Topic of Your Thesis

A THESIS

Submitted to the Department of Electronics & Communication Engineering in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

ELECTRONICS & COMMUNICATION ENGINEERING

By

SATVIR SINGH

DEPARTMENT OF FACULTY OF ENGINEERING & TECHNOLOGY

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May 2012

Topic of Your Thesis

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DECLARATION

I, SATVIR SINGH, declare that this thesis entitled, INVESTIGATIONS IN EVOLUTION OF TYPE-1 AND TYPE-2 FUZZY SYSTEMS and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for the research degree at this University.
- Wherever I have consulted the published work of others, this is always clearly attributed.
- Wherever I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Wherever the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Place: SBSCET Firozpur
Date: May 24, 2012

SATVIR SINGH

CERTIFICATE

This is to certify that the thesis entitled, INVESTIGATIONS IN EVOLUTION OF TYPE-1 AND TYPE-2 FUZZY SYSTEMS submitted by Mr. SATVIR SINGH, for the award of the degree of Doctor of Philosophy in Electronics & Communication Engineering to Maharshi Dayanand University, Rohtak (India) is a record of bonafide research work carried out by him under our guidance and supervision.

The results presented in this thesis have not been submitted to any other University for the award of any other degree or diploma.

(Supervisor)

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Future machine-intelligent systems may match, then some day exceed, our ability to learn, adapt and apply the fuzzy common-sense knowledge - knowledge that we use to run our lives and run our world.

. . . Bart Kosko

Dedicated to ***MY FAMILY***

without whose infinite support and patience

this project would never have seen the light

ABSTRACT

Your abstract goes here...

Place: SBSCET Firozpur

Date: May 24, 2012 Satvir Singh

ACKNOWLEDGEMENTS

Your acknowledgement...

Don't forget... recording your thanks to GOD for giving the environment to study, people to help, opportunities to encash and potential to succeed.

Place: SBSCET Firozpur

Date: May 24, 2012 Satvir Singh

LIST OF THESIS OUTCOMES

International/National Journal Publications/Submissions

1. S. Singh, J. S. Saini, and A. Khosla, "A MATLAB Based Versatile Toolbox for Generalized Fuzzy System Design Automation," *Applied Soft Computing (Elsevier)*, communicated.

2. S. Singh, J. S. Saini, and A. Khosla, "Designing Type-1 and Interval Type-2 Fuzzy Logic Systems from Noisy Data Set through PSO," *Expert Systems with Applications (Elsevier)*, communicated.

3. S. Singh, J. S. Saini, and A. Khosla, "Autonomous Navigational Control System for Non-holonomic Vehicles based on Interval Type-2 Fuzzy Sets," ***IEEE*** *Transactions on Systems, Man and Cybernetics - Part A*, communicated.

International/National Conference Publications

1. S. Singh and J. S. Saini, "Captive Power Management using Op-Amp based FLC," in *Proceedings of Asian Conference on Intelligent Systems & Networks*, Jagadhri (HR), India, 24-25, February 2006, pp. 160–166.

2. S. Singh and J. S. Saini, "Fuzzy FPGA based Captive Power Management," in *Proceedings, of* ***IEEE*** *Power India Conference*, Delhi, India, 10-12, April 2006. [online] Available: http://www.ieeexplore.org.

3. V. Mutneja, S. Singh, N. Gill, and J. S. Saini, "Mobile Robot Navigation using IT2-FLS," in *Proceedings **IEEE** National Conference on Intelligent Systems*, Sonipat (HR), India, 13-15, March 2008, pp. 18–23.

Contributed Book Chapters

1. **Chapter** : Nature Inspired Toolbox to Design & Optimize Systems
   Status : Proposal Accepted

2. **Chapter** : PSO Framework for Designing Fuzzy Logic Systems from Noisy Data Set
   Status : Proposal Accepted
   Authors : S. Singh, J. S. Saini, and A. Khosla
   Book Title : Machine Learning Algorithms for Problem Solving in Computational Applications: Intelligent Techniques
   Editor : Dr. Siddhivinayak Kulkarni (Sid), University of Ballarat, Australia
   Publisher : IGI Global (formerly Idea Group Inc.), USA

Software Tool Developments

1. **Generalized Fuzzy System (GFS) Toolbox**
   This is a Graphical User Interface based toolbox, developed in MATLAB environment, that helps in design automation of Fuzzy Logic Systems which may have either Type-1 and/or Interval Type-2 Fuzzy Sets. (Available online under General Public License http://sourceforge.net/projects/gfstool)

2. **Nature Inspired (NI) Toolbox**
   This Particle Swarm Optimization based optimization toolbox is developed in MATLAB environment to evolve any kind of system, especially, Type-1 and/or Interval Type-2 Fuzzy Logic Systems. This toolbox allows the exploration of most popular variants of PSO algorithms to evolve single- or multi-objective problems. (Available online under General Public License http://sourceforge.net/projects/nitool)

Tutorial Presentations

1. "Type-1 & Type-2 Fuzzy Systems," in *International Conference on Intelligent Systems & Networks*, ISTK Jagadhri (HR), India, February 15-17, 2009.

2. "Evolution of Fuzzy Systems," in MHRD/AICTE sponsored STTP on *Multi-objective Optimization Using Evolutionary Algorithms*, **ABV-IIITM** Gwalior, India (HR), December 1-5, 2008.

3. "Type-1 & Type-2 Fuzzy Systems–Modeling and Simulation," in *International Conference on Intelligent Systems & Networks*, ISTK Jagadhri, India (HR), February 26-28, 2010.

ABBREVIATIONS

Abbreviations	Description
ACO	Ant Colony Optimization
AI	Artificial Intelligence
BBO	Biogeographical Based Optimization
CCA	Continuous Curved Approximation
CUDA	Compute Unified Device Architecture
EA	Evolutionary Algorithm
EC	Evolutionary Computation
FL	Fuzzy Logic
FLC	Fuzzy Logic Controller
FLS	Fuzzy Logic System
FLT	Fuzzy Logic Toolbox
FOU	Footprint of Uncertainty
FPAA	Field Programmable Analog Array
FPGA	Field Programmable Gate Array
FS	Fuzzy Set
GA	Genetic Algorithm
gbest	Global Best

Abbreviations	Description
GC	Generalized Centroid
GFS	Generalized Fuzzy System
GPU	Graphical Processing Unit
GUI	Graphical User Interface
hbest	Hybrid Best
HSI	Habitat Suitability Index
IT2	Interval Type-2
IT2 FLS	Interval Type-2 Fuzzy Logic System
IT2 FS	Interval Type-2 Fuzzy Set
IVFS	Interval-Valued Fuzzy Set
KM	Karnik-Mendel
lbest	Local Best
LMF	Lower Membership Function
LPA	Linear Path Approximation
LUT	Look-Up Table
MF	Membership Function
NI	Nature Inspired
NP	Nonlinear and Polynomial
Op-Amp	Operational Amplifier
pbest	Previous Best
PSO	Particle Swarm Optimization
SI	Swarm Intelligence
SNR	Signal-to-Noise Ratio
T1	Type-1
T1 FLS	Type-1 Fuzzy Logic System
T1 FS	Type-1 Fuzzy Set
T2	Type-2
T2 FLS	Type-2 Fuzzy Logic System

Abbreviations	Description
T2 FS	Type-2 Fuzzy Set
TR	Type-Reduced/Reduction
TSK	Takagi-Sugeno-Kang
UMF	Upper Membership Function
UOD	Universe of Discourse

NOTATIONS

Symbols	Description
p_g	Best particle in overall swarm
p_l	Best particle in the local swarm
p_i	Best position of ith particle visited in past
φ_1	Cognitive acceleration parameter
$\overline{A}$	Complement of T1 FS (A)
χ	Constriction factor
A_e	Embedded T1 FS of $\tilde{A}$
$\tilde{A}_e$	Embedded T2 or IT2 FS of $\tilde{A}$
$\vee$	Fuzzy t-conorm (union) operator
$\bigstar$	Fuzzy t-norm (general) operator
$\wedge$	Fuzzy t-norm (minimum) operator
$\int$	Fuzzy union over continuous universe of discourse
$\sum$	Fuzzy union over discrete universe of discourse
w	Inertia weight
$\underline{\mu}_{\tilde{A}}(x)$	LMF of T2 or IT2 FS ($\tilde{A}$)
V_{max}	Maximum particle velocity
$\mu_A(x)$	MF for T1 FS (A)

Symbols	Description
$\mu_{\tilde{A}}(x)$	MF of T2 or IT2 FS ($\tilde{A}$)
x_i	Present position of ith particle in PSO or ith input to an FLS
v_i	Present velocity of ith particle
J_x	Primary membership grade over $x \in X$
φ_2	Social acceleration parameter
$\cup$	T1 fuzzy t-conorm (union) operator
$\cap$	T1 fuzzy t-norm (intersection) operator
$\tilde{A}$	T2 FS (A)
$\sqcup$	T2 fuzzy t-conorm (join) operator
$\sqcap$	T2 fuzzy t-norm (meet) operator
$\neg\tilde{A}$	T2 fuzzy negation operation of $\tilde{A}$
/	Tuple
$\overline{\mu}_{\tilde{A}}(x)$	UMF of T2 or IT2 FS ($\tilde{A}$)
X	Universe of discourse of x

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

GUIDELINE FOR THESIS WRITING

1.1 Don't Worry....here

This "LaTeX Thesis Template", is very easy to use for writing a thesis. [1]

LaTeX facilitates in writing high quality, professionally typeset documents that run to hundreds or thousands of pages long. One of its main strengths is the way it can typeset equations those are the most horribly twisted. It automatically generates:

- Title Page,
- Fixes the margins,
- Sets headers and footers,
- Table of Contents,
- List of Figures,

- List of Tables,
- Equations, Figures and Tables Numbers
- Updates Equations, Figure, Table and Bibliographic referencing
- Bibliography
- Index at the end ... many more

and above all keeps the formatting consistent, beautiful and worth presentable.

1.1.1 LaTeX eBooks

Further, four most useful (free) eBooks downloaded from various websites are given here in **eBooks on LaTeX** folder for your help. You can go through and/or refer to them as and when required. Just for beginner here are some points to remember in reference to LaTeX, after one or two page typesetting these become obvious:

- Backslash (\) is used to write LaTeX commands. If you need to use backslash in your text, you should write $\backslash$.
- Curl Braces ({ or }) are used to pass arguments to LaTeX commands. For using them in text put backslash before as \{ or \}.
- Dollar Sign ($) is used to write mathematics in line. However, Dollar sign can be used in text as \$.
- Ampersand (&) is distinguish column in the tables. However, this can also be used in text similar to Dollar sign as \&
- Bibtex file (.bbl) may require to be updated (Accessories → BibTex) if some references are removed or formatting style is changed.
- Similarly, index Files (.idx) required to be updated (Accessories → Make Index) sometimes.

- If some error occurs during compilation then some output LaTeX files, e.g, .pdf, .aux etc., may get corrupted. Before recompilation, remove errors in .tex file and erase all output files (Tools → Erase Output Files) to avoid inconvenience.
- You need not to remember any command for mathematical symbols. These all are given in WinEdt Toolbar. Just click and use within $ signs or equation environments.

1.1.2 Required Software to be Installed

The best thing is that its all freeware available on internet. You need to install followings on you PC/Laptop

- **MikTex 2.8** (LaTeX Software) — You need to download from www.miktex.org (Size 780MB) or get it from your department office.
- **JabRef 2.5** (Bibtex Utility Software) — Given here in the **Primitives** folder as size is smaller. JabRef 2.5 sometimes requires to be updated from internet after installation.
- **WinEdt 2.5** (Latex Text Editor) — As size is smaller it is given herewith in the **Primitives** folder with Registration Key in text file.

1.2 Personalize the 'Thesis.cls' File

You will need to personalize the thesis template and make it your own by filling in your own information. This is done by editing the lines numbers 155-170 (shown below) of the 'Thesis.cls' file in any text editor.

```
%===============================================================
%=======================PERSONALIZE THIS TEXT===================
%===============================================================
\UNIVERSITY : {\texorpdfstring{\href{http:\\www.dcrustm.ac.in}
                {\textbf{MAHARSHI DAYANAND UNIVERSITY}\\ ROHTAK - 124001 (HR) INDIA}}
```

```
                {\textbf{MAHARSHI DAYANAND UNIVERSITY}\\ ROHTAK - 124001 (HR) INDIA}}
\COLLEGE        {}
\DEPARTMENT {Electrical Engineering Department}
\SUBJECT        {Instrumentation & Control}
\ROLLNO         {316049601}
\SUPERVISOR   {\texorpdfstring{\href{jssain@rediffmail.com}{Dr. J. S. Saini}}{Dr. J. S. Saini}}
\DESIGNATION {Professor & Chairman, EED}
\DEGREE         {DOCTOR OF PHILOSOPHY}
%================================================================
%=======================PERSONALIZE THIS TEXT====================
%================================================================
```

1.3 Personalize the '`Thesis.tex`' File

The `Thesis.tex` file contains the structure of the thesis. Initially there seems to be a lot of LaTeX code, but this is all formatting, you don't have to do it yourself.

Begin by personalizing the title page by filling your own TITLE (line number 43), AUTHORS-name-email (line number 44), and KEYWRODS (line number 45) in the TEX preamble. Author can enable any of the two following options for documentclass as per requirements (and same in bibliography section) in line number 20-25.

```
% OPTION 1 (AUTHOR-YEAR BIBLIOGRAPHY)

%\documentclass[a4paper, 12pt, oneside]{Thesis}

%\usepackage[square, comma, authoryear, sort&compress]{natbib}

% OPTION 2 (IEEE FORMAT BIBLIOGRAPHY)

\documentclass[a4paper, 12pt, oneside]{Thesis}

\usepackage[square, numbers, comma, sort&compress]{natbib}
```

Next comes the declaration, abstract, and acknowledgements, etc. Double click on the respective **\input** and modify as you like. Declaration page requires changes in author name, title and supervisor name, otherwise its ok. Do not forget to acknowledge your parents, partners and supervisor in acknowledgements page.

The table of contents, list of figures and list of tables are all taken care of for you and no need to create or edit manually.

For Abbreviations and Notations, an **Front Matter Tables.xls** file is given herewith. Keep on updating both sheets as you write your thesis. Copy and paste in respective `.tex` files, after sorting in MS excel itself, as and when you need to compile finally.

Thesis chapter(s) can be included or excluded just by putting/removing % sign in/from the start of respective line(s). This helps in handling longer thesis easily.

After the preamble, chapters and appendices finally comes the bibliography. The bibliography style (called '`IEEEtran`') is used for the bibliography and is a fully featured style that will even include links to where the referenced paper can be found online. Do not under estimate how grateful you reader will be to find that a reference to a paper is just a click away.

1.4 Thesis Features and Conventions

To get the best out of this template, there are a few conventions that you may want to follow. One of the most important and most difficult things is to remember changes required to be done in thesis like long documents. You can prepare a ToDo.doc file for keeping track of things to do that makes the job easier. Of course, all of these are optional and you can adopt your own method.

1.4.1 Printing Format

This thesis template is designed for single sided printing as most theses are printed and bound this way. This means that the left margin is always wider than the right (for binding). The headers for the pages contain the page number on the right side (so it is easy to flick through to the page you want) and the chapter name on the left side.

The text is set to 12 point and a line spacing of 1.3. Generally, it is much more readable to have a smaller text size and wider gap between the lines than it is to have a larger text size and smaller gap. Again, you can tune the text size and spacing should you want or need to. The text size can be set in the options for the '`\documentclass`' command at the top of the '`Thesis.tex`' file and the spacing can be changed by setting a different value in the '`\setstretch`' commands (scattered throughout the '`Thesis.tex`' file).

1.4.2 Common Grammatical Mistakes

Following are some of the common mistakes that are generally committed by the students while writing their Dissertation report and thus to be avoided:

1. **Spacing between words and punctuation marks**: The spacing between words and punctuation marks (comma, colon, semicolon, apostrophe's, underscore, hyphen, etc.) should be proper. One may take care of followings:
   - no space between a word and the proceeding comma or full stop,
   - space after and before '&' or 'and',
   - space before and after a dash but no space before and after hyphen.
   - Dash is used as a separator or to indicate the meaning of the proceeding clause, and
   - hyphen is used as a connector between two words.
2. **Sentence making**:
   - The sentence must have some meaning, noy only implicit to the author but also clear/explicit to the reader, e.g., "Now we set the length of a chromosome as following terms:..." The sentence is not meaningful. Instead, the correct sentence could be "Now we set the chromosome length as follows:..."

- The sentence should normally not be very lengthy with so many commas or other punctuation marks, etc. The sentence must be to the point and crisp.
- The sentence should always start with the first letter of first word as capital. There should not ne any capital letter(s) unnecessarily in between the sentence, except proper nouns, symbols, abbreviations, etc., e.g., "Holmblad L.P. and osttergaard..." the first letter of the name must be capital, so it be Ostergaard

3. **Vocabulary**: The student must focus on this point too because if vocabulary is not precise, the sentence can't bear proper meaning, e.g., complex rather than complexive, etc. In case of words with similar meaning (e.g., estimation/approximation/detection etc.), select the best suited word for the sentence.

4. **Grammatical mistakes**: It includes the proper use tense, helping verbs, etc. The proper noun, i.e., name of any specific person, animal, place, river, etc. should start with a capital letter, e.g., "We learned..." (it should be "We learnt...") and "Now we sets..." (it should be "Now we set...")

5. **Spelling mistakes**: The student should confirm about the spellings, if in doubt, from the standard dictionary, e.g., "The gas is then passed trough rotary air heater." (Here wrong spelling of "through" is used as "trough").

6. **Use of Symbols & Abbreviations**: If symbols are to be used in the text, they must be defined prior to use and there must be proper presentation of symbols with consistent subscripts and/or superscripts, if any, e.g., "X(t0)" is wrong it should be "$X(t_0)$". "t–time", "t–dummy integration variable". As the meaning of the symbol t is different at these two places, so there must be separate notation for the variable carrying different meanings. All abbreviated terms and used symbols may be expanded in a Abbreviations and Notations respectively, to be placed just before Table of Content.

7. **Text Formation**:

- To make the text precise and meaningful, there should not be any duplicacy of sentence and the text should be duly paragraphed.
- Each chapter should have a soft start and a soft wind up, i.e., each chapter have an Introduction section at the start and a Conclusion section at the end of the chapter.
- All the tables and figure must be captioned properly.
- To show continuity used only \ldots (3 dots).
- Typing error should especially be taken care of.
- The use of the first person should be avoided, e.g., "I attempted the use of casual knowledge in modeling the plant." should better be rephrased as: "In this dissertation or chapter, the use of casual knowledge has been attempted in modeling the plant."
- We refer past literature in papers, however, should be discussed using Present Tenses only rather than Past Tenses.
- Last Sentence of the abstract should point out conclusions, improvements and/or findings etc. Maximum efforts should be made to write positive sentence, even if it is negative.
- No sentence should start with "Because" word. If require, "As" word should be used.
- Clauses should remain within commas. Check sentence conveys proper meaning, if we remove clause.
- Special care should be taken for singular and/or plural objects/subjects.

8. **Evidential text**: The text should itself should speak or provide all the information, i.e., whatever you have done, there must be evidence or proof of that work in your text. Claiming about anything without proof is always considered as fake, e.g., "A new robust neuro-fuzzy controller for autonomous and intelligent robot manipulations has been design" is a fake statement or a shallow claim unless proof or evidence is given for the design. "See the section on loop tuning" shall be false or fake statement if there is no section of loop tuning given by the candidate.

9. **Units citation**: The units must be put at all their requisite places because without units, the data can have ambiguous meaning.

10. Do not use double quotes etc. around equation numbers, just braces are sufficient.

11. **Other technical mistakes**: The student should gather proper technical information before writing the dissertation. The wrong information present wrong impression about one's work and abilities, e.g., If some kind of data is given in the text then it must be significant to the text otherwise useless extension of the text should be avoided.

12. One may even refer to the IEEE Guidelines for Authors submitting paper to IEEE Journals.

1.5 Useful Entries

1.5.1 References

The '`natbib`' package is used to format the bibliography and inserts references such as this one. The options used in the '`Thesis.tex`' file mean that the references are listed in numerical order as they appear in the text. Multiple references are rearranged in numerical order and multiple, sequential references become reformatted to a reference range. This is done automatically for you.

References should come *after* nearer the word or clause is referred to, e.g., "Fuzzy sets of type-2 are simplified by Mendel [2]". Multiple citations in different square brackets can also be specified, e.g., "Many research studies has been reported on type-2 fuzzy sets [3–7]" or multiple citations can come in single set of square brackets, e.g., "Many research studies has been reported on type-2 fuzzy sets [3–8]."

The footnotes[1] can also enrich your document. Footnotes themselves should be full, descriptive sentences (beginning with a capital letter and ending with a full stop).

[1]Such as this footnote, here down at the bottom of the page.

1.6 Figure

Let's discuss how user can include into his/her THESIS. I suggest the following: figure should be prepared or inserted in MS Word 2007 (resize page or figure to fit in page fully), convert into pdf and then inserted into tex file as follows:

FIGURE 1.1: Figure Caption Here - Electron

1.6.1 Refering a Figure

One can refer to a figure in TEXfile Fig. 1.1

1.7 Table

Many a times we got to design in our THESIS. Here it is the way

TABLE 1.1: Table Caption Here

Transformation	**Equation**
$\Phi \rightarrow \Phi'$	$\Phi' = \Phi + \sin^{-1}[(v/d).\sin\theta_T]$
$x \rightarrow x'$	$x' = x + d.\cos\Phi + v.\cos\gamma - d.\cos\Phi'$
$y \rightarrow y'$	$y' = y + d.\sin\Phi + v.\sin\gamma - d.\sin\Phi'$

alternatively, tables can be prepared in MS Office and inserted into tex as figure. For example

TABLE 1.2: PSO simulation results for 2000 iterations

1.7.1 Refering a Table

Refer to any table using label as Table 1.1 or Table 1.2

1.8 Equation

. . . when Einstein introduced his formula

$$e = m \cdot c^2 \tag{1.1}$$

Eq. 1.1 is at the same time the most widely known and the least well understood physical formula.

. . . from which follows Kirchhoffs current law:

$$\sum_{k=1}^{n} I_k = 0 \, . \tag{1.2}$$

Kirchhoffs voltage law can be derived . . . (refer Eq. 1.2)

1.8.1 Refer Equation

One can refer to any equation using label specified by the Eq 1.3.

. . . which has several advantages.

$$I_D = I_F - I_R \tag{1.3}$$

is the core of a very different transistor model. . . .

1.9 Index Terms

To specify any word in the THESIS index as Thesis

1.10 Common Mistakes

Dr. J. S. Saini has prepared some guideline for writing quality matter. User can refer to these guidelines for improvements.

1.11 Template Folders

Appendices – this is the folder where you put the appendices. Each appendix should go into its own separate '`.tex`' file.

BackMatter – this is folder that contain all the material that is required at the end of thesis, e.g., Reference.bib, Resume.tex and authors photo, etc.

Chapter$X$ – these are the folder where you put the thesis chapters. A thesis usually has about seven chapters ($X = 1, 2...7$), though there is no hard rule on this. Each chapter should go in its own separate '`.tex`' file and they usually are split as:

- Chapter1: Introduction to the thesis topic

- Chapter2: Background information and theory
- Chapter3: (Laboratory) experimental setup
- Chapter4: Details of experiment 1
- Chapter5: Details of experiment 2
- Chapter6: Discussion of the experimental results
- Chapter7: Conclusion and future directions

Chapter$X$/Figures – this folder in the Xth chapter folder that contains the all figures related to Chapter$X$ of the thesis. These are the final **pdf** images that will go into the thesis document.

FrontMatter – this is folder that contain all the material that is required before the thesis Chapters start, e.g., Abreviattion.tex, Abstract.tex, Acknowledgement.tex, Declaration.tex, Logo.pdf, and Notation.tex, etc.

eBooks on LaTeX – Four useful eBooks on LaTeX are given in this folder to help the authors.

Missing Packages – Some useful packages are provided herewith those may be missing in installed software.

Primitives – this is the folder that contains scraps, particularly because one final image in the 'Figures' folder may be made from many separate images and photos, these source images go here. This keeps the intermediate files separate from the final thesis figures.

1.12 Other LaTeX Files in Main Folder

Included are also several files, most of them are plain text and you can see their contents in a text editor. Luckily, many of them are auxiliary files created by LaTeX or BibTeX and which you don't need to bother about:

Bibliography.bib – this is an important file that contains all the bibliographic information and references that you will be citing in the thesis for use with BibTeX. You can write it manually, but there are reference manager programs available that will create and manage it for you. Bibliographies in LaTeX are a large subject and you may need to read about BibTeX before starting with this.

Thesis Todo List.txt – this is a Todo list that provides a simple way to track the thesis progress and also helps you see what parts need attention. Inside is a structured layout for you to enter all this information. Do not try to fill it out all at once, but write the tasks in as you come across them i.e. write an entry for a figure that needs creating only when you refer to or write about it (and hence need to place it) in the thesis text.

Thesis.cls – this is an important file. It is the style file that tells LaTeX how to format the thesis. You will also need to open this file in a text editor and fill in your own information (such as name, department, institution). Luckily, this is not too difficult and is explained in section 1.2 on page 3.

Thesis.pdf – this is your beautifully typeset thesis (in the PDF file format) created by LaTeX.

Thesis.tex – this is an important file. This is the file that you tell LaTeX to compile to produce your thesis as a PDF file. It contains the framework and constructs that tell LaTeX how to layout the thesis. It is heavily commented so you can read exactly what each line of code does and why it is there. After you put your own information into the '`Thesis.cls`' file, go to this file and begin filling it in – you have now started your thesis!

vector.sty – this is a LaTeX package, it tells LaTeX how to typeset mathematical vectors. Using this package is very easy and you can read the documentation on the site (you just need to look at the '`vector.pdf`' file):
http://www.ctan.org/tex-archive/macros/latex/contrib/vector/

lstpatch.sty – this is a LaTeX package required by this LaTeX template and is included as not all TeX distributions have it installed by default. You do not need to modify this file.

Files that are *not* included, but are created by LaTeX as auxiliary files include:

Thesis.aux – this is an auxiliary file generated by LaTeX, if it is deleted LaTeX simply regenerates it when you run the main '`.tex`' file.

Thesis.bbl – this is an auxiliary file generated by BibTeX, if it is deleted, BibTeX simply regenerates it when you run the main tex file. Whereas the '`.bib`' file contains all the references you have, this '`.bbl`' file contains the references you have actually cited in the thesis and is used to build the bibliography section of the thesis.

Thesis.blg – this is an auxiliary file generated by BibTeX, if it is deleted BibTeX simply regenerates it when you run the main '`.tex`' file.

Thesis.lof – this is an auxiliary file generated by LaTeX, if it is deleted LaTeX simply regenerates it when you run the main '`.tex`' file. It tells LaTeX how to build the 'List of Figures' section.

Thesis.log – this is an auxiliary file generated by LaTeX, if it is deleted LaTeX simply regenerates it when you run the main '`.tex`' file. It contains messages from LaTeX, if you receive errors and warnings from LaTeX, they will be in this '`.log`' file.

Thesis.lot – this is an auxiliary file generated by LaTeX, if it is deleted LaTeX simply regenerates it when you run the main '`.tex`' file. It tells LaTeX how to build the 'List of Tables' section.

Thesis.out – this is an auxiliary file generated by LaTeX, if it is deleted LaTeX simply regenerates it when you run the main '`.tex`' file.

So from this long list, only the files with the '`.sty`', '`.bib`', '`.cls`' and '`.tex`' extensions are the most important ones. The other auxiliary files can be ignored or deleted as LaTeX and BibTeX will regenerate them.

1.13 In Closing

You have reached the end of this mini-guide. You can now rename or overwrite this pdf file and begin writing your own '`Chapter1.tex`' and the rest of your thesis. The easy work of setting up the structure and framework has been taken care of for you. It's now your job to fill it out! If you use this Thesis template and this mini-guide helps you, please let me know[2].

Good luck and have lots of fun!

Satvir Singh Sidhu

[2]Email: satvir15@gmail.com all comments and suggestions, questions and errata are welcome.

APPENDIX A

TEST FUNCTIONS FOR OPTIMIZATION METHODS

There is a suite of benchmark functions [9, 10] which are commonly used to critically test the performance of numeric optimization algorithms. These functions are chosen because of their particularities, which render their optimization difficult. These comprise

- Multi-modality
- Deceptive gradient information
- The curse of dimensionality

A.1 Sphere/DeJong

This function is very simple. Any algorithm capable of numeric optimization should solve it without any problem. Its simplicity helps to focus on the effects of dimensionality in optimization algorithms. It is unimodal, with its global minimum located at

$x = \langle 0, \ldots, 0 \rangle$, with $f(x) = 0$. This function has no interaction between its variables and gradient information always points toward the global minimum.

Function	:	$f(\langle x \rangle) = \sum_{i=1}^{n} x_i^2$
Search Space	:	$\{\langle x_i \rangle | \forall i : -100 \leq x_i \leq +100\}$
Dimensionality	:	30
Minimum	:	0
Maximum	:	$3 \cdot 10^5$
Criterion	:	$f(x) \leq 0.01$

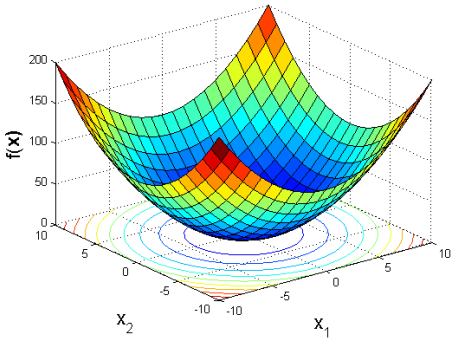

FIGURE A.1: Graph of *Sphere* function in two dimensions

A.2 Rosenbrock

Not all unimodal functions are simple to optimize. The fitness landscape is simple from afar but banana shaped when close to the minimum. Rosenbrock's variables are strongly dependent and gradient information often misleads algorithms. Its global minimum of $f(x) = 0$ is located at $x = \langle 1, \ldots, 1 \rangle$.

Function	:	$f(\langle x \rangle) = \sum_{i=1}^{n-1} 100(x_{i+1} - x^2)^2 + (x_i - 1)^2$
Search Space	:	$\{\langle x_i \rangle | \forall i : -30 \leq x_i \leq +30\}$
Dimensionality	:	30
Minimum	:	0
Maximum	:	2508237869
Criterion	:	$f(x) \leq 100$

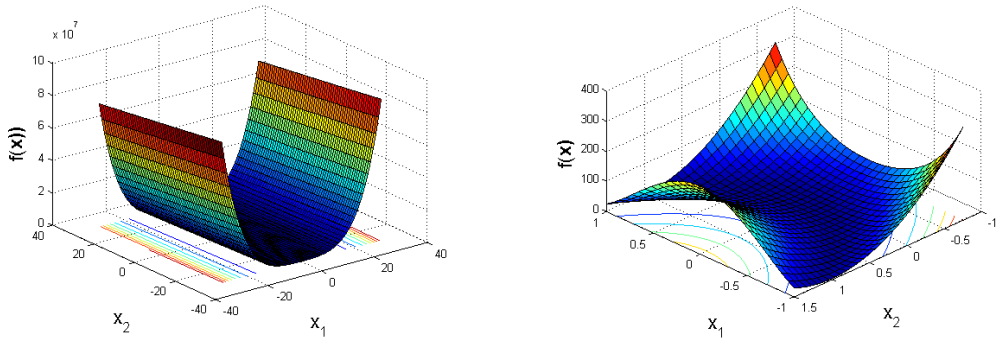

FIGURE A.2: Graph of *Rosenbrock* function in two dimensions

A.3 Ackley

Ackley is a multi-modal function with many local optima. The global minimum is $f(x) = 0$, where $x = 0$. This function is difficult because optimization algorithms can easily be trapped in a local minimum on its way to the global minimizer.

Function	:	$f(\langle x \rangle) = 20 + e - 20e^{-0.2\sqrt{\frac{\sum_{i=1}^{n} x_i^2}{n}}} - e^{\frac{\sum_{i=1}^{n} \cos 2\pi x_i}{n}}$
Search Space	:	$\{\langle x_i \rangle | \forall i : -30 \leq x_i \leq +30\}$
Dimensionality	:	30
Minimum	:	0
Maximum	:	22.35040
Criterion	:	$f(x) \leq 0.01$

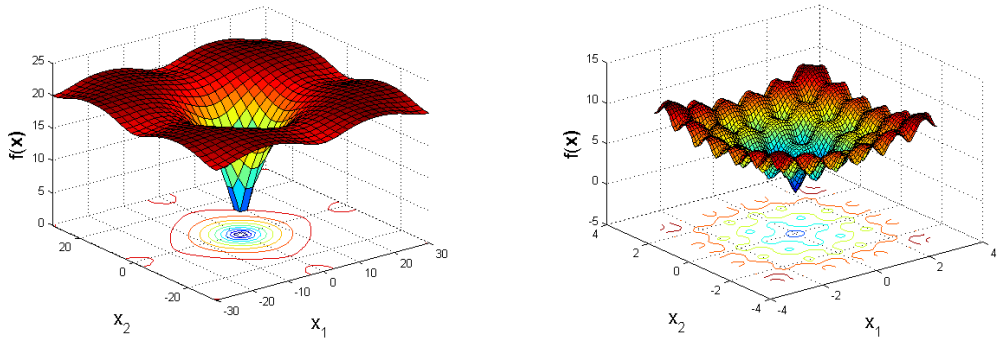

FIGURE A.3: Graph of *Ackley* function in two dimensions

A.4 Rastrigin F1

A multi-modal version of the Spherical function, characterized by deep local minima arranged as sinusoidal bumps. The global minimum is $f(x) = 0$, where $x = 0$. An optimization algorithm can easily become trapped in a local minimum on its way to the global minimizer.

Function	:	$f(\langle x \rangle) = \sum_{i=1}^{n} x_i^2 - 10 \cos 2\pi x_i + 10$
Search Space	:	$\{\langle x_i \rangle | \forall i : -5.12 \leq x_i \leq +5.12\}$
Dimensionality	:	30
Minimum	:	0
Maximum	:	1210.6
Criterion	:	$f(x) \leq 100$

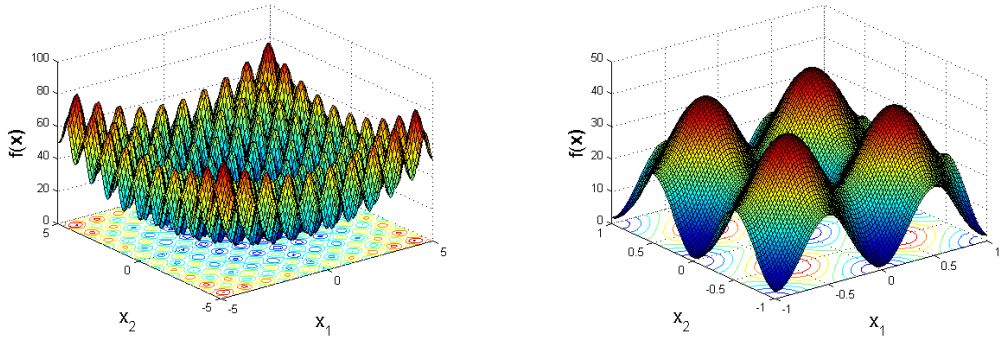

FIGURE A.4: Graph of *Rastrigin* function in two dimensions

A.5 Griewank

This function is strongly multi-modal with significant interaction between its variables, caused by the product term. This function has the interesting property that the number of local minima increases with dimensionality. However, the influence of the product term also diminishes dramatically in these circumstances. In fact, it becomes negligible once the $n > 30$. The common benchmark used in the literature is when $n = 30$. The global minimum, $x = \langle 100, 100, ..., 100 \rangle$, yields a function value of $f(x) = 0$.

Function	:	$f(\langle x \rangle) = 1 + \frac{\sum_{i=1}^{n}(x_i - 100)^2}{4000} - \prod_{i=1}^{n} \cos \frac{x_i - 100}{\sqrt{i}}$
Search Space	:	$\{\langle x_i \rangle | \forall i : -600 \leq x_i \leq +600\}$
Dimensionality	:	10 and 30
Minimum	:	0
Maximum	:	1666.839 and 3676.839
Criterion	:	$f(x) \leq 0.05$

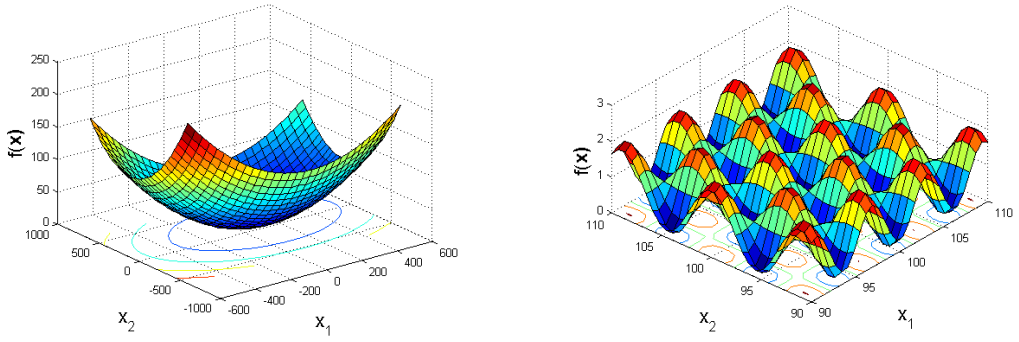

FIGURE A.5: Graph of *Griewank* function in two dimensions

A.6 Schaffer F6

This is a very difficult function, especially devised to trick optimization algorithms with its many local optima arranged in concentric circles around the global optimum that is itself located in a narrow basin.

Function	:	$f(\langle x \rangle) = 0.5 + \frac{\sin(\sqrt{x_1^2 + x_2^2})^2 - 0.5}{(1 + 0.001(x_1^2 + x_2^2))^2}$
Search Space	:	$\{\langle x_i \rangle | \forall i : -100 \leq x_i \leq +100\}$
Dimensionality	:	2
Minimum	:	0
Maximum	:	1
Criterion	:	$f(x) \leq 0.00001$

On the zoom of Fig. A.6, the inner contour line represents the area of points with values lower than the ones located in the outer belt of local optima. Only these values

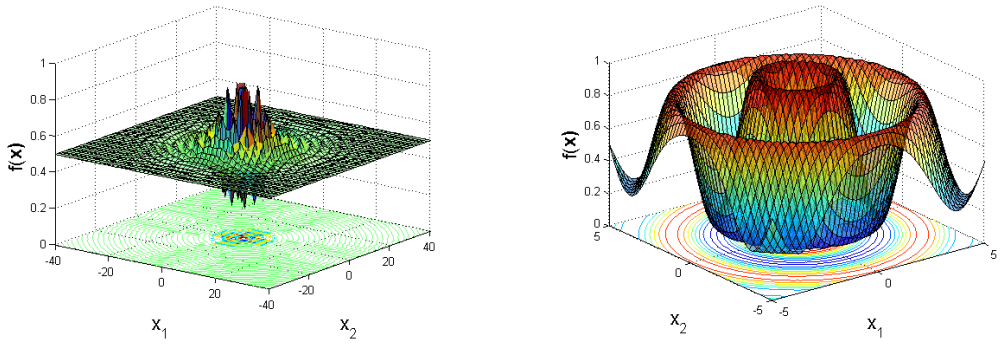

FIGURE A.6: Graph of *Schaffer* function in two dimensions

lead to the global best. Optimization algorithms are usually stuck on that belt and unable to converge on the global optimum whose fitness is zero.

* * * * *

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INDEX

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