

Thesis, Dissertation and Technical Report Styles in L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> for the  
University of New Mexico

Second Edition

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August 1, 2000

## Part I

# The unmeethesis Style

## 1 Overview

This style is intended to produce a thesis or dissertation which conforms to the requirements for such documents issued by the Office of Graduate Studies (OGS) at the University of New Mexico. However, differences in  $\text{\LaTeX} 2_{\epsilon}$  implementations and printers may result in variations of the output format. It is your responsibility to check with the OGS to ensure that fonts, margins, and line spacing meets their criteria for publication, based on your specific hardware/software  $\text{\LaTeX} 2_{\epsilon}$  implementation. In order to use this dissertation style you *must* be using  $\text{\LaTeX} 2_{\epsilon}$ . Check with your system administrator for the correct pathnames to  $\text{\LaTeX} 2_{\epsilon}$ . Many systems still have the older  $\text{\LaTeX} 2.09$  implementation and it is *not* compatible with this style sheet. If both versions exist, the path to the  $\text{\LaTeX} 2_{\epsilon}$  binary must precede that of the outdated  $\text{\LaTeX} 2.09$  implementation. Ask your system administrator for help in setting your `PATH` environment variable, if necessary. This variable can be checked by entering the command `printenv PATH` at the shell prompt (or in some cases, simply by entering `env`).

You must also have installed the following configuration files for this style sheet to work properly:

- 1) `unmeethesis.cls` (for a thesis or dissertation)
- 2) `unmeereport.cls` (for a technical report)
- 3) `unm10.clo`, `unm11.clo`, `unm12.clo` (size specifications for point sizes 10, 11, 12)
- 4) `template.tex` [optional!] (complete, working thesis example to use as your template)

These files are available from the OGS website. Alternatively, they can be found on the mirror website <http://www.math.unm.edu/~nedoren/latex> in the subdirectory `style_sheets`. It is possible to have your administrator install them into the appropriate system areas (he/she will know where) but alternatively, you can put them in your working dissertation directory, and  $\text{\LaTeX} 2_{\epsilon}$  will know to find them there. In many cases, these files have already been installed on your network by your administrator. If so, you may proceed immediately with the authoring of your thesis or dissertation, if you are confident the system style files are up to date. If these files are installed in your local working directory as well as the system areas, your local copies will take precedence. Having local copies is advantageous because custom modifications can be made to your style without affecting the system-wide copy. Furthermore, system administrators are not always prompt in installing the latest version available from OGS. Thus, you may be using an outdated version, or worse yet, when the system copies are modified, your dissertation format may change without your knowing it. It is your responsibility to make sure your style sheet is up to date by keeping copies locally. The OGS website will always have the latest version available for download. While this puts the burden on the user for acquiring the latest style sheet, it is necessary since the style sheet authors have no idea which systems have which versions installed.

In order to use this style your  $\text{\LaTeX} 2_{\epsilon}$  document must begin with the command

```
\documentclass[list of options]{unmeethesis},
```

where *list of option* is a list of elements separated by commas without any space (e.g., *option1,option2,...*). The `unmeethesis` style has the following options

|           |         |         |
|-----------|---------|---------|
| 10pt      | 11pt    | 12pt    |
| oneside   | twoside |         |
| draft     | final   |         |
| openright | openany |         |
| leqno     | fleqn   | openbib |
| nobox     | botnum  |         |

The default options are `12pt`, `oneside`, `draft`, and `openright`. All of these options have the same meaning as those defined for the standard `report` style in [Lam94, page 177], *except* the `draft` option. Two of the pages of the dissertation have red boxes around them. These boxes are the thick black boxes shown in Figures 1 and 5. These red boxes are defined and drawn in the proper color in the `unmeethesis` style. Unfortunately the dvi previewer `xdvi` does not display pages containing color properly. To avoid this difficulty, the `draft` option draws these boxes in black rather than red, so that `xdvi` can display these pages. If the `final` option is selected, then these boxes are drawn in red. In that case the document can only be viewed properly with the POSTSCRIPT previewer `ghostview`. Note that the very first page of the front matter is *not* produced by `unmeethesis`. This page is the one for the signatures of your thesis/dissertation committee members. This page can be purchased at the UNM book store.

The last two options, `nobox` and `botnum` are unique to the `unmeethesis` style. The `nobox` option turns off the boxes on the title and dissertation abstract page. This option allows these specific pages to be printed on blank paper, without the box frames, should one choose to add the red border box separately via color laserjet, inkjet printer, etc. The `botnum` option moves all page numbers so they are centered at the bottom of the page. By default, page numbers appear at the upper right hand corner of the page, just inside the margins, as specified by the OGS. In either case, consistency in page number location is maintained in both front matter and main body sections, as per OGS requirements. Numbering pages at the bottom slightly increases the bottom margin; consequently, recheck floating diagrams and equations after modifying the page number location to ensure proper diagram positions.

A typical style specification for a thesis or dissertation would be

```
\documentclass[fleqn, botnum]{unmeethesis}
```

Next, enter the command pair

```
\begin{document}
```

```
\end{document}
```

Place all of the following commands after `\begin{document}` and before `\end{document}`. The

front section of the dissertation contains a number of pages that are required by graduate studies. When these pages are numbered at all, they have Roman numerals. The numbers are printed or suppressed automatically, according to the OGS publishing guidelines. They appear at the upper right by default, or centered at the bottom if the `botnum` option is specified. Collectively, all of these pages are called the front matter. To begin this section of the dissertation type the following command.

`\frontmatter`

The first page of the dissertation is required to be the title page. To create this title page the following commands are *required*.

`\title{your dissertation title}`

`\author{your name}`

`\previousdegrees{your previous degrees}`

`\maketitle`

If `\title{}`, `\author{}` and `\previousdegrees{}` do not appear before `\maketitle` you will receive cryptic error messages from L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> which indicate that `\maketitle` is an undefined command. The reason for this is that no default values for `\title{}`, `\author{}` and `\previousdegrees{}` are defined, and without these values the title page can not be created. The command `\maketitle` actually creates the properly formatted title page. Optional commands that should *precede* `\maketitle` are

| <u>Command</u>  | <u>Default Value</u>  | <u>Valid Option</u>                              |
|---|---|--|
| <code>\date{desired date}</code>                                  | <code>\today</code>   | <i>desired month</i> , <code>\thisyear</code>    |
| <code>\degree{your current degree name}</code>                    | Doctor of Philosophy<br>Engineering                                       | Master of Science in<br>Engineering (Math, etc.) |
| <code>\degreesubject{your current degree name and subject}</code> | Ph.D., Electrical Engineering   | M.S., Electrical Engineering                     |
| <code>\documenttype{your document name}</code>                    | Dissertation  | Thesis   |
| <code>\schoolname{your school name}</code>                        | University of New Mexico  |  |
| <code>\schooladdress{your school address}</code>                  | Albuquerque, New Mexico   |  |
| <code>\degreetext{text to introduce your degree name}</code>      | Submitted in Partial Fulfillment of the \\ Requirements for the Degree of |  |

For anyone attending the University of New Mexico, only the first four optional commands should ever be required. The optional values for `\degree{}`, `\degreesubject{}`, and `\documenttype{}`

should be used by Masters candidates, the defaults are correct for Doctoral candidates. Note that in `unmeetthesis` the command `\today` has been modified to return *month, year* (e.g., December, 1995) *not month day, year* (e.g., December 16, 1995). The command `\thisyear` returns just the current year (e.g., 1995).

The next page of the dissertation is an optional copyright page. This page can be produced if desired by entering the following command.

```
\makecopyright
```

The next page is an optional dedication page, which is constructed using the next command.

```
\begin{dedication}  
text of your dedication  
\end{dedication}
```

By default the text on this page is right justified. The text can be left justified or centered by placing the dedication text within the commands `\begin{flushleft} text \end{flushleft}` or `\begin{center} text \end{center}` respectively. The following page is an optional acknowledgments page, formatted with the following command.

```
\begin{acknowledgments}  
text of your acknowledgments  
\end{acknowledgments}
```

The next page is the required title page for the abstract of the dissertation. This is produced by simply entering the next command.

```
\maketitleabstract
```

The next page contains the required abstract of the dissertation, and is produced with the following command.

```
\begin{abstract}  
text of your abstract  
\clearpage %needed only if a single page abstract  
\end{abstract}
```

The next sections are required and must be in the following order; table of contents, list of figures, and list of tables. They are produced with the series of commands shown below.

```
\tableofcontents  
\listoffigures  
\listoftables
```

Note that if your dissertation has no figures or tables then the last two commands are not required. The last section in the front matter is an optional glossary of terms used in your dissertation. This

is constructed with the command

```
\begin{glossary}{the longest term that you will define}  
text of your glossary  
\end{glossary}
```

The longest term that you plan to define must be given to the `glossary` environment because it indents every definition by the width of the longest term. This is illustrated in Figures 12 and 13 where  $\text{Diag}(m_1, m_2, \dots, m_n)$  is the longest term defined, and every definition is indented by its width. After this, enter the next command to begin the main part of your dissertation.

```
\mainmatter
```

After this, proceed with the remainder of your dissertation as if you were using the standard report style. All of the page style parameters discussed in [Lam94, page 181–182] are set by default in `unmeethesis`. You are strongly cautioned *against* changing these values in the preamble of your document. Such changes are likely to produce very odd page formatting results.

## 2 Suggested References for Learning $\text{\LaTeX} 2_\epsilon$

This document focuses on the  $\text{\LaTeX} 2_\epsilon$  specifics for creating a UNM dissertation or thesis using the `unmeethesis` style. Obviously, this information is not available in a general purpose  $\text{\LaTeX} 2_\epsilon$  reference book. For those needing basic information on  $\text{\LaTeX} 2_\epsilon$  document preparation, there are a number of excellent books covering the basics (and advanced features) of  $\text{\LaTeX} 2_\epsilon$ . The reader is encouraged to obtain the following books, which are two of the best: [Lam94, Goo94].

Integrating graphics into  $\text{\LaTeX} 2_\epsilon$  documents is an art in itself. While the most basic form of graphics inclusion is not at all difficult, that of encapsulated POSTSCRIPT (EPS), users sometimes have unique requirements for image manipulation, scaling or annotation, as well as the desire to include other types of images (JPG, TIF, PDF, etc.). The book [Goo97] provides detailed, if not somewhat esoteric coverage of graphics integration into  $\text{\LaTeX} 2_\epsilon$  documents. The reference books mentioned here can be found in most bookstores or purchased online from [amazon.com](http://www.amazon.com) at <http://www.amazon.com>. There are a multitude of other books available, depending on your needs and interests.

$\text{\LaTeX} 2_\epsilon$  is **not** a word processor. It has no built-in text editor, page previewer, spelling checker or printer drivers. These additional packages and utilities, in conjunction with the  $\text{\LaTeX} 2_\epsilon$  package, comprise the set of tools needed to write a thesis. A list of public-domain support programs and a brief description of their use can be found in the accompanying document `TEXTIPS`, which is available via the OGS website. As an alternative, it can be downloaded from the mirror website, <http://www.math.unm.edu/~nedoren/latex> in the subdirectory `user_manuals` under filename `textips.ps` (POSTSCRIPT) or `textips.pdf` (ADOBE PDF).

### 3 Known Bugs in the `unmeethesis` Style

This section discusses the (known) quirks, limitations, and odd behaviors to be encountered when using the `unmeethesis` style sheet. The authors make no claim that this list is exhaustive. Nor are there any guarantees that the style can be adapted to meet every author's specific requirements. A large number of people will using this style, and undoubtedly, more bugs will be uncovered due to the many incarnations and scenarios for its use. Please report bugs to the authors. An effort will be made to remedy those bugs felt to adversely affect a large number of users.

It is hoped that any particular formatting or layout concern can be addressed via  $\text{\LaTeX}$  2 $\epsilon$  commands embedded within your document. Thus, it should never be necessary to make modifications to the  $\text{\TeX}$  `unmeethesis.cls` file. In fact, doing so could have disastrous results. If you modify this file, always keep a copy of the original to fall back on. If you feel the `unmeethesis` style has a serious bug (other than those listed here), contact the author.

Idiosyncrasies in the `unmeethesis` style:

1. The optional sections in the front matter are **Dedication** and **Acknowledgments**. All others are required to maintain the proper page count and a consistent format. For example, the copyright page may not be omitted.
2. If a single-page **Abstract** is desired (common for a Master's thesis), then a `\clearpage` command must be issued just prior to the `\end{abstract}` command. This ensures proper pagination and margin formatting.
3. A **Dedication** page, if included, should be limited to a single page (check with OGS for specific requirements). Thus, no automatic pagination is performed if this section covers two pages. The user must manually paginate the **Dedication** in this case, using the following command at the desired point of pagination:

```
{\clearpage \vspace*{3.5em} \noindent}
```

4. Formatting and pagination are consistent only for the 12pt font size. This is the default font, and that required by the OGS.

### 4 Contacting the Author

The `unmeethesis` style and associated documentation is maintained by Neall Doren. He can be reached via email at [nedoren@sandia.gov](mailto:nedoren@sandia.gov). Please report any unknown bugs, anomalies, or suggestions for changes to Dr. Doren, via email only. The document you are reading is available via the OGS website. As an alternative, it can be downloaded from the mirror website <http://www.math.unm.edu/~nedoren/latex> in the subdirectory `user_manuals` under filename `styles.ps` (POSTSCRIPT) or `styles.pdf` (ADOBE PDF).

## 5 Dissertation Style Example in L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub>

Next, an example taken from a doctoral dissertation prepared with the `unmeethesis` style. It is hoped that the L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> source code shown below will give the reader sufficient understanding of the necessary commands and options for the dissertation and thesis style sheet. Subsequently, it should be a simple matter to expand this example into a unique dissertation. Actual L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> output follows this source code example.

```
\begin{document}

\frontmatter

\title{Space-Variant Post-Filtering for Wavefront Curvature Correction
       in Polar-Formatted Spotlight-Mode SAR Imagery}
\author{Neall Evan Doren}
\previousdegrees{B.S., University of Southern Colorado, 1983 \\\
                 M.S., Electrical Engineering, University of New Mexico, 1991}
\date{December, \thisyear}
\maketitle

\makecopyright

\begin{dedication}
  To my parents, Carl and Horty Doren, for their support,
  encouragement and love. \\\[3ex]
  To my wife, Maribeth, for her countless sacrifices and endless
  patience and understanding. \\\[3ex]
  To my favorite high school teacher, Terry J. Cyprian, whose faith in me
  some twenty years ago will never be forgotten. Teachers {\bf \em do}
  make a difference. \\\[8ex]
  ‘‘Never, never, never give up’’
      -- Winston Churchill
\end{dedication}

\begin{acknowledgments}
  I would like to thank my advisor, Professor Neeraj Magotra, for his
  encouragement and continued support of my work. I would also like to
  thank my manager, Dr. Jack Jakowatz, for unselfishly offering his time
  and expert technical advice to this effort. He has been an inspiration
  both professionally and spiritually, and he originally proposed this
  interesting and valuable research topic. I am also grateful to my
  dissertation committee for their time and efforts. ...
  :
\end{acknowledgments}
```



---

```

\maketitleabstract

\begin{abstract}
  Wavefront curvature defocus effects occur in spotlight-mode SAR imagery
  when reconstructed via the well-known polar-formatting algorithm (PFA)
  under certain imaging scenarios. These include imaging at close range,
  using a very low radar center frequency, utilizing high resolution, and/or
  imaging very large scenes. ...
  :
  % uncomment next line for single page abstract (for proper page number loc).
  % \clearpage

\end{abstract}

\tableofcontents
\listoffigures
\listoftables

\begin{glossary}{Longest string}
  \item[$a_{lm}$]
    Taylor series coefficients, where  $l,m = \{0..2\}$ 
  \item[$A_{\boldsymbol{p}}$]
    Complex-valued scalar denoting the amplitude and phase of a radar return.
  \item[$A^T$]
    Transpose of phase history data (as done in polar-format algorithm).
  :
\end{glossary}

\mainmatter

\chapter{Introduction}
\section{\label{section:overview}Overview}
  The classic approach to SAR image formation from phase history data
  collected in the spotlight-mode has been the polar-format algorithm (PFA).
  This algorithm was developed in 1974 by Dr. Jack Walker and served as the
  basis of his Ph.D. dissertation \cite{Walker:1974}. ...
  :

\chapter*{Appendices}
\addcontentsline{toc}{chapter}{Appendices}
% Next lines duplicated from .toc file and used to create mini
% "Appendix Table of Contents," if desired:
\contentsline {chapter}{\numberline {A}IPR Broadening Due to Quadratic Phase

```

```
Errors}{205}
\contentsline {section}{\numberline {A.1}IPR Broadening Based on
Spectral Width}{209}
\contentsline {section}{\numberline {A.2}Spatial Domain IPR Broadening}{211}
% End mini table of contents

\appendix
\chapter{IPR Broadening Due to Quadratic Phase Errors}
The {\em impulse response function}\ (IPR) is used to describe the radar
system's response to a single isolated point target return and is described
mathematically by the dirac delta function  $g(u)=\delta(u)$ , arbitrarily
located at  $u=0$ . ...

:
\end{document}
```

Examples of the POSTSCRIPT output created by running the dvi to POSTSCRIPT converter dvips on this L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> code are shown in Figures 1–19.

**Space-Variant Post-Filtering for Wavefront  
Curvature Correction in Polar-Formatted  
Spotlight-Mode SAR Imagery**

by

**Neall Evan Doren**

B.S., University of Southern Colorado, 1983

M.S., Electrical Engineering, University of New Mexico, 1991

DISSERTATION

Submitted in Partial Fulfillment of the  
Requirements for the Degree of

Doctor of Philosophy  
Engineering

The University of New Mexico

Albuquerque, New Mexico

December, 1999

**Figure 1:** Dissertation Title Page

Last Revision: August 1, 2000

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©1999, Neall Evan Doren

**Figure 2:** Dissertation Copyright Page

Last Revision: August 1, 2000

## Dedication

*To my parents, Carl and Horty Doren, for their support, encouragement and love.*

*To my wife, Maribeth, for her countless sacrifices and endless patience and  
understanding.*

*To my favorite high school teacher, Terry J. Cyprian, whose faith in me some  
twenty years ago will never be forgotten. Teachers **do** make a difference.*

*“Never, never, never give up” – Winston Churchill*

**Figure 3:** Dissertation Dedication Page

Last Revision: August 1, 2000

## Acknowledgments

I would like to thank my advisor, Professor Neeraj Magotra, for his encouragement and continued support of my work. I would also like to thank my manager, Dr. Jack Jakowatz, for unselfishly offering his time and expert technical advice to this effort. He has been an inspiration both professionally and spiritually, and he originally proposed this interesting and valuable research topic. I am also grateful to my dissertation committee for their time and efforts.

The generous educational benefits provided by Sandia Laboratories<sup>1</sup>, as well as easy access to their leading-edge Instructional Television Services (ITV), allowed me the opportunity to pursue my dreams. I am grateful to my managers past and present: Dr. Jakowatz, Dr. Larry Stotts, Dr. Jim Baremore and Ms. Dori Ellis, for allowing me to utilize these company benefits and helping me to realize my full potential.

Additional thanks are extended to Ms. Julie Kesti of Sandia Labs' technical library for her literature searches and prompt document delivery, and to the "Lunatic Fringe," a group of talented SAR engineers including Drs. Dennis Ghiglia, Paul Thompson, and Dan Wahl, who were instrumental to my success. Dr. Wahl's suggestions became the basis of many of my computer simulations and he authored the RMA and FReD simulations used in the comparisons of Chapter 6. Dr. Thompson aided in my understanding of the theoretical mathematical models and described to me the mathematics of the broadside phase model. Dr. Ghiglia provided insight into the effects of phase errors on IPR broadening and first derived the formulas of Appendix A. A note of appreciation goes to Mrs. Joan Lillie, whose administrative expertise and kindness kept me from falling through the cracks. Furthermore, my thanks to Dr. James W. Howse, my close friend and fellow graduate student, and Dr. Ireena Erteza, who (gently) prodded me and kept me inspired, excited and motivated through the good times and bad. Also, to Dr. Don Hush, who provided so much encouragement and support over the past 15 years, in addition to serving on my committee. Last but not least, a big thanks to Mrs. Erika Papp, who kept me sane through thick and thin. Many thanks to all.

---

<sup>1</sup>This work was supported by the US Department of Energy under contract No. DE-AC04-94AL85000. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

**Figure 4:** Dissertation Acknowledgment Page

**Space-Variant Post-Filtering for Wavefront  
Curvature Correction in Polar-Formatted  
Spotlight-Mode SAR Imagery**

by

**Neall Evan Doren**

**ABSTRACT OF DISSERTATION**

Submitted in Partial Fulfillment of the  
Requirements for the Degree of

Doctor of Philosophy  
Engineering

The University of New Mexico

Albuquerque, New Mexico

December, 1999

**Figure 5:** Dissertation Title of Abstract Page

Last Revision: August 1, 2000

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# **Space-Variant Post-Filtering for Wavefront Curvature Correction in Polar-Formatted Spotlight-Mode SAR Imagery**

by

**Neall Evan Doren**

B.S., University of Southern Colorado, 1983

M.S., Electrical Engineering, University of New Mexico, 1991

Ph.D. Electrical Engineering, University of New Mexico, 2000

## **Abstract**

Wavefront curvature defocus effects occur in spotlight-mode SAR imagery when reconstructed via the well-known polar-formatting algorithm (PFA) under certain imaging scenarios. These include imaging at close range, using a very low radar center frequency, utilizing high resolution, and/or imaging very large scenes. Wavefront curvature effects arise from the unrealistic assumption of strictly planar wavefronts illuminating the imaged scene. This dissertation presents a method for the correction of wavefront curvature defocus effects under these scenarios, concentrating on the generalized, squint-mode imaging scenario and its computational aspects. This correction is accomplished through an efficient one-dimensional, image domain space-variant filter applied as a post-processing step to PFA. This space-variant post-filter, referred to as SVPF, is precalculated from a theoretical derivation of the wavefront curvature effect and varies as a function of scene location. Prior to SVPF, severe

**Figure 6:** First Dissertation Abstract Page

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restrictions were placed on the imaged scene size in order to avoid defocus effects under these scenarios when using PFA. The SVPF algorithm eliminates the need for scene size restrictions when wavefront curvature effects are present, correcting for wavefront curvature in broadside as well as squinted collection modes while imposing little additional computational penalty for squinted images.

This dissertation covers the theoretical development, implementation and analysis of the generalized, squint-mode SVPF algorithm (of which broadside-mode is a special case) and provides examples of its capabilities and limitations as well as offering guidelines for maximizing its computational efficiency. Tradeoffs between the PFA/SVPF combination and other spotlight-mode SAR image formation techniques are discussed with regard to computational burden, image quality, and imaging geometry constraints. It is demonstrated that other methods fail to exhibit a clear computational advantage over polar-formatting in conjunction with SVPF. This research concludes that PFA in conjunction with SVPF provides a computationally efficient spotlight-mode image formation solution that solves the wavefront curvature problem for most standoff distances and patch sizes, regardless of squint, resolution or radar center frequency. Additional advantages are that SVPF is not iterative and has no dependence on the visual contents of the scene, resulting in a deterministic computational complexity which typically adds only thirty percent to the overall image formation time.

**Figure 7:** Second Dissertation Abstract Page

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## Glossary

|                |  |
|----------------|--|
| $a_{lm}$       | Taylor series coefficients, where $l, m = \{0..2\}$  |
| $A_p$          | Complex-valued scalar denoting the amplitude and phase of a radar return.                                      |
| $A^T$          | Transpose of phase history data (as done in polar-format algorithm).   |
| $A_x$          | Physical width of the antenna in the along-track (azimuth) direction.  |
| $B_c$          | Bandwidth of linear FM chirp.  |
| $\beta_a$      | Cone angle of beam at radar antenna.   |
| $C_{fft}$      | Complex operations count for an FFT.   |
| $C_p$          | Overall complex operations count.  |
| $C_{p/pix}$    | Complex operations count, per pixel.   |
| $C_{f/pix}$    | Floating point operations count, per pixel.  |
| $C_{optf/pix}$ | Optimal floating point operations count, per pixel. Based on optimal filter length $m_{opt}(c)$ for some $c$ . |
| CRP            | Central reference point of a spotlight-mode collection. Typically the scene center.                            |

**Figure 12:** First Dissertation Glossary Page

*Glossary*

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|                                     |  |
|-------------------------------------|--|
| CSA                                 | Chirp scaling algorithm. Simplified RMA image formation via approximation (chirp-Z transform) instead of Stolt interpolation.                      |
| CW                                  | Continuous wave (non-FM range pulse).  |
| $c$                                 | Speed of light.  |
| $c$                                 | (Maximum) overlap between adjacent space-variant filter applications.  |
| $c_b, c_s$                          | Overlap between adjacent space-variant filter applications, broadside and squint collection geometries, respectively.                              |
| $D$                                 | Physical diameter of radar antenna.  |
| $D_p$                               | Patch diameter of imaged scene.  |
| $d$                                 | (Maximum) displacement in cross-range from the previous space-variant filter application.  |
| $d_b, d_s$                          | Displacement in cross-range from previous space-variant filter application, broadside and squint collection geometries, respectively.              |
| $d_{opt}$                           | Optimal displacement in cross-range from previous space-variant filter application, yielding lowest operations count for some filter overlap $c$ . |
| $d_{x'_0, y'_0}(X', Y')$            | Point target response of $(x'_0, y'_0)$ for the frequency extent $X'$ and $Y'$ .   |
| $\Delta f_0$                        | Nominal spectral width of IPR.   |
| $\Delta f_{QPE}$                    | Nominal spectral width of quadratic phase error signal $e^{jat^2}$ .   |
| $\frac{\Delta f_{QPE}}{\Delta f_0}$ | IPR broadening factor.   |
| $\Delta_{IPR}$                      | IPR broadening factor.   |

**Figure 13:** Second Dissertation Glossary Page

Last Revision: August 1, 2000

# Chapter 1

## Introduction

### 1.1 Overview

The classic approach to SAR image formation from phase history data collected in the spotlight-mode has been the polar-format algorithm (PFA). This algorithm was developed in 1974 by Dr. Jack Walker and served as the basis of his Ph.D. dissertation [1]. Later, this work was published in the *IEEE Transactions on Aerospace and Electronic Systems* journal [2] and patented in 1980 [3]. The polar-format algorithm is still popular today because of its straightforward implementation and robustness in constructing images of large scenes without introducing phase discontinuities. In contrast to the stripmap-mode SAR, which is a radar with a fixed look angle for a given collection (see Figure 1.1), the spotlight-mode SAR slews its antenna as the aperture is flown, thereby staying aimed at the scene center for the entire duration of the collection, as shown in Figure 1.2. Due to its extended dwell time on a given scene, the spotlight-mode SAR is capable of higher along-track resolutions and typically requires less transmit power than the strip-map SAR. The disadvantage of spotlight-mode SAR is that a smaller ground patch is imaged compared to strip-map SAR. However, it is possible (and in fact common) to mosaic spotlight-mode images into larger image patches.

**Figure 14:** First Page of Dissertation Introduction Chapter



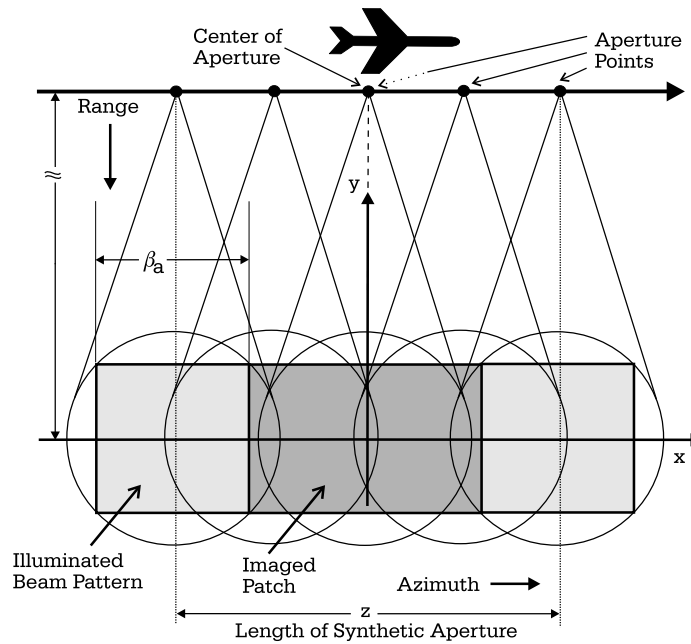


Figure 1.1: Stripmap-Mode SAR Imaging Geometry

In polar-formatting, the collected phase history data are described in terms of a slice of the three-dimensional Fourier transform of the scene reflectivity, obtained on a polar raster, as shown in Figure 1.3 (a). Known as the *tomographic approach to SAR*, the analogy between spotlight-mode SAR and tomography was first proposed by David C. Munson and his colleagues, and presented formally in 1983 [4]. It was then revisited and recast by Ausherman, et. al. [5]. Munson's method expounded on the preliminary work of Walker, yet failed to cover several important points. For instance, the imaging of three dimensional (elevated) targets was not discussed in Munson's paper. A complete three-dimensional tomographic model that was later developed by Jakowatz and Thompson accounts for range-dependent layover in the scene [6]. Jakowatz, et al, [7, pp. 355–365] in 1996 addressed the effects of certain

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## Appendix A

### IPR Broadening Due to Quadratic Phase Errors

The *impulse response function* (IPR) is used to describe the radar system's response to a single isolated point target return and is described mathematically by the dirac delta function  $g(u) = \delta(u)$ , arbitrarily located at  $u = 0$ . The system is necessarily bandwidth limited and the IPR is a sinc function response. The spatial bandwidth for a spotlight-mode collection is given by

$$\Delta U_y = \Delta Y' = \frac{2}{c} (2\pi B_c) \quad (\text{range extent}) \quad (\text{A.1})$$

and

$$\Delta U_x = \Delta X' = 2 \left( \frac{4\pi}{\lambda} \right) \sin(\Delta\theta/2) \quad (\text{azimuth extent}), \quad (\text{A.2})$$

where  $B_c$  is the bandwidth of the linear FM chirp launched by the radar at a center frequency of  $\omega_0$ ,  $\Delta\theta$  is the angular diversity of the synthetic aperture, and  $\lambda$  is the signal wavelength at  $\omega_0$ . Since the angular diversity  $\Delta\theta$  is typically very small in spotlight-mode SAR collections, the small angle approximation  $\sin(\theta) = \theta$  can be applied to Equation (A.2), yielding

$$\Delta U_x \approx \frac{4\pi}{\lambda} \Delta\theta. \quad (\text{A.3})$$

**Figure 17:** First Page of Appendix

## Appendix A. IPR Broadening Due to Quadratic Phase Errors

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The *prime* (') in  $\Delta X'$  and  $\Delta Y'$  signify that these frequency extents apply to the slant plane reconstruction as opposed to the ground plane projection. The IPR reconstruction consists of a mainlobe and associated sidelobes with the first zero crossings occurring at a distance of  $u = \pm \frac{2\pi}{\Delta U}$ , as shown in Figure A.1. A full derivation of Equations (A.1) and (A.2) can be found in [7, pp. 22–24, 72–74]. Since *resolution* refers to the ability to distinguish between two adjacent IPRs, one can assume they must be separated by at least the distance  $u$ . In fact, while this simplistic assumption does provide a certain useful and practical measure of resolution, it does not take into account the relative phases of the reflected point target signals, which can further degrade resolution. Another commonly used measure of resolution  $\rho$  is the *half-power width* of the ideal response function such that in general,

$$\rho = \frac{\pi}{\Delta U} \quad (\text{A.4})$$

and specifically,

$$\rho_{y'} = \frac{\pi}{\Delta U_y} = \frac{\pi}{Y'_1} \quad (\text{A.5})$$

and

$$\rho_{x'} = \frac{\pi}{\Delta U_x} = \frac{\pi}{X'_1} \quad (\text{A.6})$$

for the range and azimuth resolutions, respectively, where  $X'_1$  and  $Y'_1$  define the maximum frequency extent of the aperture in the slant plane, where ( $|\Delta U_x| \leq X'_1$ ) and ( $|\Delta U_y| \leq Y'_1$ ). Again, this measure is optimistic whenever the relative phases of the reflected point target signals are not considered.

The IPR sidelobes also have an effect on image quality. In SAR imaging, it is desirable to limit the peak sidelobe levels of the IPR because high sidelobes confuse the signatures of complex, closely spaced scattering centers, making visual analysis difficult or confusing. This sidelobe energy is generally concentrated in the range and azimuth directions only, with little diagonal energy present. This is due to a phase history which is typically rectangular in shape (after interpolation), with the

**Figure 18:** Second Page of Appendix

Chapter 4. Analysis of Phase Errors Arising From Wavefront Curvature

and by substitution from Equation (4.52),

$$b_{01} \Big|_{\substack{X=0, \\ Y=k_0}} = r_c . \quad (4.78)$$

Having determined  $b_{01}$  at aperture center, the linear phase coefficient  $a_{01}$  given by Equation (4.71) can also be evaluated at the aperture center, as follows:

$$a_{01} \Big|_{\substack{X=0, \\ Y=k_0}} = r_0 - \frac{1}{b_{01} \Big|_{\substack{X=0, \\ Y=k_0}}} (r_0^2 - \rho^2 - 2\rho r_0 \sin(\gamma)) \quad (4.79)$$

and by Equation (4.78),

$$a_{01} \Big|_{\substack{X=0, \\ Y=k_0}} = r_0 - \frac{r_0^2 - \rho^2 - 2\rho r_0 \sin(\gamma)}{r_c} . \quad (4.80)$$

Finally, again by Equation (4.52),

$$a_{01} \Big|_{\substack{X=0, \\ Y=k_0}} = r_0 - \frac{r_c^2}{r_c} = r_0 - r_c , \quad (4.81)$$

where, as previously shown,

$$r_c = \sqrt{r_0^2 + x_0'^2 + y_0'^2 - 2r_0 y_0'} \quad (\text{Equation (4.67)})$$

for the slant plane target position  $(x_0', y_0')$  and range  $r_0$  from the scene center to radar platform at mid-aperture. The Taylor coefficient  $a_{01}$ , when multiplied by the range frequency extent  $Y'$ , determines the linear phase component in range of a point target at  $(x_0', y_0')$ . That is, from Equation (4.12), the linear range phase term  $\phi_{1t_y}$  is

$$\phi_{1t_y} = a_{01} Y' \quad (4.82)$$

$$= (r_0 - r_c) Y' , \quad (4.83)$$

where  $Y'$  is the Fourier frequency extent in range. As with the linear cross-range component, this phase term contains the linear phase component  $y_0' Y'$  that serves

## Part II

# The unmeereport Style

## 1 Overview

This style is intended to produce a well formatted technical report for the Department of Electrical and Computer Engineering at the University of New Mexico. In order to use this technical report style you *must* be using L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub>. Check with your system administrator for the correct pathnames to L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub>. Many systems still have the older L<sup>A</sup>T<sub>E</sub>X 2.09 implementation and it is **not** compatible with this style sheet. If both versions exist, the path to the L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> binary must precede that of the outdated L<sup>A</sup>T<sub>E</sub>X 2.09 implementation. Ask your system administrator for help in setting your PATH environment variable, if necessary. This variable can be checked by entering the command `printenv PATH` at the shell prompt (or in some cases, simply by entering `env`).

In order to use this style, your L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> document must begin with the command

```
\documentclass[list of options]{unmeereport},
```

where *list of option* is a list of elements separated by commas without any space (e.g., *option1,option2,...*). In terms of command use this class is identical to the **report** class documented in [Lam94] with the following exceptions.

- 1) The **unmeereport** style has the same options as the standard **report** style in [Lam94, page 177], *except* the **notitlepage** | **titlepage** option does not exist. The title and abstract pages are always formatted as separate pages. There is a new set of options **section** | **chapter** which selects the top level division in the document as either a **section** (e.g., the article format) or a **chapter** (e.g., the report format). The default is the **section** option.
- 2) The abstract is no longer entered as `\begin{abstract} text \end{abstract}` Instead it is entered as `\abstract{text}`.
- 3) There is a new command `\reporttype{text}`. The name of the report type should be entered inside the curly braces. The default is `\reporttype{UNM Technical Report: EECE}`.
- 4) There is a new command `\techrepnum{text}`. The technical report number should be entered inside the curly braces. For example for technical report EECE95-003, the proper command is `\techrepnum{95--003}`. The default is `\techrepnum{}`.
- 5) There is a new command `\keywords{text}`. The keywords, if any, should be entered inside the the curly braces. The default is `\keywords{}`.
- 6) There is a new command `\acknowledge{text}`. The acknowledgments, if any, should be entered inside the the curly braces. The default is `\acknowledge{}`.

- 7) There is a new command `\makeabstract`. This is analogous to the command `\maketitle` except it composes the abstract page. It must be placed after the `\abstract`, `\keywords`, and `\acknowledge` commands.
- 8) The commands `\reporttype`, `\techrepnum`, `\keywords`, `\acknowledge`, and `\date` are all optional, if they are not entered the default values are used. The default value of `\date` is `\date{\today}`.

Notice that by using the commands `\reporttype{}` and `\techrepnum{}`, other types of reports can be prepared with this style. For instance, for the final report for contract W-300445, use the commands `\reporttype{Final Report: Contract }` and `\techrepnum{W--300445}`. Now a rather long example taken from a technical report prepared with this style will be presented.

### Report Example: L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> code

```
\begin{document}

\title{A Synthesis of Gradient and Hamiltonian Dynamics Applied to Learning in
Neural Networks}

\author{\mbox{James W. Howse \hspace*{2em} Chaouki T. Abdallah \hspace*{2em}
Gregory L. Heileman} \\\[2ex]
Department of Electrical and Computer Engineering \\\
University of New Mexico \\\
Albuquerque, NM 87131}

\techrepnum{95--003}

\date{August 5, 1995}

\maketitle

\abstract{%
The process of model learning can be considered in two stages: model
selection and parameter estimation. In this paper a technique is presented
for constructing dynamical systems with desired qualitative properties.
:
}

\keywords{Dynamical systems, System Identification}

\acknowledge{This research was supported by a grant from Boeing Computer
Services under Contract \mbox{W--300445}. The authors would like to thank
Vangelis Coutsias, Tom Caudell, Don Hush, and Bill Horne for stimulating
discussions and insightful suggestions.}
```

```
\makeabstract
```

```
\chapter{Introduction}
```

```
%
```

```
A fundamental problem in mathematical systems theory is the identification of  
dynamical systems. System identification is a dynamic analogue of the pattern  
recognition problem. A set of input-output pairs  $(u(t), y(t))$  is given over  
some time interval  $t \in [\tau_i, \tau_f]$ . The problem is to find a model
```

```
:
```

```
\end{document}
```

Examples of the POSTSCRIPT output created by running the dvi to POSTSCRIPT converter dvips on this L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> code are shown in Figures 20–23.



DEPARTMENT OF ELECTRICAL AND  
COMPUTER ENGINEERING  
  
SCHOOL OF ENGINEERING  
  
UNIVERSITY OF NEW MEXICO

**A Synthesis of Gradient and Hamiltonian Dynamics Applied to  
Learning in Neural Networks**

James W. Howse      Chaouki T. Abdallah      Gregory L. Heileman

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University of New Mexico  
Albuquerque, NM 87131

UNM Technical Report: EECE95-003

Report Date: August 5, 1995

**Figure 20:** Report Title Page

Last Revision: August 1, 2000

### Abstract

The process of model learning can be considered in two stages: model selection and parameter estimation. In this paper a technique is presented for constructing dynamical systems with desired qualitative properties. The approach is based on the fact that an  $n$ -dimensional nonlinear dynamical system can be decomposed into one gradient and  $(n - 1)$  Hamiltonian systems. Thus, the model selection stage consists of choosing the gradient and Hamiltonian portions appropriately so that a certain behavior is obtainable. To estimate the parameters, a stably convergent learning rule is presented. This algorithm is proven to converge to the desired system trajectory for all initial conditions and system inputs. This technique can be used to design neural network models which are guaranteed to solve certain classes of nonlinear identification problems.

### Key Words

Dynamical systems, System Identification

### Acknowledgments

This research was supported by a grant from Boeing Computer Services under Contract W-300445. The authors would like to thank Vangelis Coutsias, Tom Caudell, Don Hush, and Bill Horne for stimulating discussions and insightful suggestions.

**Figure 21:** Report Abstract Page

Last Revision: August 1, 2000

## Chapter 1

# Introduction

A fundamental problem in mathematical systems theory is the identification of dynamical systems. System identification is a dynamic analogue of the pattern recognition problem. A set of input-output pairs  $(u(t), y(t))$  is given over some time interval  $t \in [\tau_i, \tau_f]$ . The problem is to find a model which for the given input sequence returns an approximation of the given output sequence. Broadly speaking, solving an identification problem involves two steps. The first is choosing a class of identification models which are capable of emulating the behavior of the actual system. For non-linear identification, a common model choice is a recurrent neural network. One reason for this is that it was shown by Sontag (1992) and Funahashi and Nakamura (1993) that certain classes of recurrent networks can approximate an arbitrary dynamical system over a compact set for a finite time interval. Several recurrent models for system identification were proposed in Narendra and Parthasarathy (1990). In a similar vein, a set of constructive recurrent models were introduced in Cohen (1992). While the expressed purpose of these models was associative memory, they can be modified for use in system identification by including an appropriate term for the system inputs.

The second step in system identification involves selecting a method to determine which member of the class of models best emulates the actual system. In Narendra and Parthasarathy (1990) the model parameters are learned using a variant of the back-propagation algorithm. No learning algorithm is proposed for the models in Cohen (1992). Similar to the problem of learning model parameters for system identification is the problem that is often referred to in the literature as “trajectory following”. Algorithms to solve this problem for continuous time systems have been proposed by Pearlmutter (1989), Sato (1990), and Saad (1992) to name only a few. One problem with all of these algorithms is that to our knowledge, no one has ever proven that the error between the learned and desired trajectories vanishes. The difference between system identification and trajectory following is that in system identification one wants to obtain an approximation which is good for a broad class of input functions. Conversely, in trajectory following one is often concerned only with the system performance on the small number of specific inputs (i.e. trajectories) that are used in learning. Nevertheless these trajectory following algorithms could be applied to parameter estimation for system identification.

In this paper we present a class of nonlinear models and an associated learning algorithm. The learning algorithm guarantees that the error between the model output and the actual system vanishes. Our class of models is based on those in Cohen (1992), with an appropriate system input. We show that these systems are one instance of the class of models generated by decomposing the dynamics into a component normal to some surface and a set of components tangent to the same surface. Conceptually this formalism can be used to design dynamical systems with a variety of desired qualitative properties. Our learning procedure is related to one discussed in Narendra and Annaswamy (1989) for use in linear system identification. This learning procedure allows the parameters of Cohen's models to be learned from examples rather than being programmed in advance. We prove that this learning algorithm is

**Figure 22:** First Report Introduction Page

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## Introduction

convergent in the sense that the error between the model trajectories and the desired trajectories is guaranteed to vanish.

This paper is organized as follows. In Section 2 the decomposition of dynamics into a component normal to some surface and a set of components tangent to the same surface is discussed. Section 3 is a brief review of one of the potential design techniques introduced in Cohen (1992). The learning algorithm and some theorems about its behavior are given in Section 4. In Section 5 the results of some computer simulations are presented. The proofs for all of the theorems are given in the Appendix.

**Figure 23:** Second Report Introduction Page

## References

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