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Poisson Kernel Estimates of Lexigraphic Matrices

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A thesis presented in partial fulfillment of the requirements of the Undergraduate Honors Program at the University of New Haven.

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_____ May 2015

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ABSTRACT

Poisson Kernel Estimates of Lexigraphic Matrices

by Jane Q. Student

May 2015

In this study we examine the suitability of efficiently inverting, or obtaining the solution of problems associated with a class of centrosymmetric matrices which arise from problems associated with stochastic interpolation on regularly spaced grids. These matrices associated with these linear systems are full, and thus the usual range of sparse matrix solvers are not available. In particular, the study focuses directly on the properties of centrosymmetric matrices as a means to improve the solvability of these linear systems, showing that for these centrosymmetric matrices of even order it is possible to achieve a factor of $7/8$ improvement in the cost of matrix inversion using Schur complements. In addition the multiplication of these matrices can be speeded up by a factor of two by fully utilizing the block antisymmetry of these matrices.

Acknowledgments

I would like to thank my advisor Dr. Strange Strangelove for guidance throughout the project, and Dr. Tom Clown for the help with everything else, and everyone else for financial support.

Dedication

This work is dedicated to my family, especially my mother and father. Their encouragement throughout this process made this a reality.

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Chapter 1

Introduction

1.1 Background

A square matrix has the same number of rows as it does columns, and it represents a linear system in which the number of unknowns exactly matches the number of equation, and thus it represents a linear system which may have a unique solution. The size of an $n \times n$ matrix is referred to as the order of the matrix n , and this equals the number of rows or columns in a square matrix.

Finally, in terms of notation, it will be convenient to refer to the matrix A in terms of its coefficients, using the notation $A = (a_{ij})$. For example, if we multiply the matrix A by the constant c , then $cA = c(a_{ij}) = (ca_{ij})$ and we demonstrate through this notational device that matrix multiplication is equivalent to multiplying each entry in the matrix by the constant c . This standard notational tool will prove useful in regard to demonstrating some properties of matrices that are needed in this study.

1.2 A special matrix of interest: a centrosymmetric matrix

A matrix with a particular structure, or a specific form associated with the pattern of the coefficients is called a *special matrix*. A special matrix need not be complicated, as in the case of the diagonal matrix already discussed, or it can be much more intricate in the layout of its coefficients in some regular pattern. The primary focus of this study is on centrosymmetric matrices, although even at this level of specialization, not every centrosymmetric matrix will be of interest to us. The centrosymmetric matrices that are of interest are those which arise from problems associated with stochastic interpolation.

Centrosymmetric matrices¹ follow a pattern in which the coefficients of the matrix are reflected about the center of the matrix [2], i.e., the coefficients of the matrix A are rotationally symmetric about the center. Alternatively, we can define a centrosymmetric matrix such that $A = EAE$, where $E = (e_n, e_{n-1}, \dots, e_1)$ is the exchange matrix, and e_k is the k -th standard basis vector in \mathbb{R}^n . In this description, the coefficients of the matrix progress

¹These are sometimes referred to as perplectic matrices.

lexicographically for the first half of the rows in the matrix, and then regress through these same coefficients listed in reverse lexicographic order from the bottom row to the middle row, if the matrix is of even order. If it is of odd order, the middle row is symmetric about its center. Perhaps the easiest way to conceptualize this pattern is through language using palindromes. When read backwards, a palindrome produces the same sentence when read both forwards and backwards as in the sentence, “Go hang a salami, I’m a lasagna hog.”

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1.3 Developments

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Chapter 2

Methodology

2.1 Introduction to technical writing

This is the introduction section. This should involve a brief discussion of the purpose of the report, what concepts are essential, and what will be investigated. Use this template for writing your analysis files. If you examine this file closely, it has some very useful features in it that will set up your paper so that it has a more professional appearance. You should also review the rules for typesetting L^AT_EX.

Be mindful of some simple rules in using English:

1. Do not use the first person singular in a formal report. Use the first person plural or the third person in a passive construction. Thus
I did this work, is unacceptable, while, *We did this work*, or *This work was done*, are acceptable.
2. When typesetting mathematics, use punctuation. All math equations must read as if they were English sentences. You must end these with a period, and put commas where needed.
3. Keep the verb tense constant. Do not switch from past to present, and then back again, and then back again to the present. There may be a need to do this, however be careful when you are doing it.
4. Avoid colloquial English. These are formal reports. These are not email messages to your friends. Be aware that some words in English such as *big* are colloquial, and do not appear in formal writing. Do not use *very* to modify every adjective. It is usually meaningless.

Get a manual on English usage and style from the library, or purchase one from the bookstore. Realize that if you plan to stay in academia, or get an administrative position in a company or a laboratory, you have to be able to communicate effectively. Work on this skill.

Then be mindful of some simple rules for typesetting L^AT_EX:

1. Note that the previous sentence beginning this list is not indented since it does not begin a new paragraph. To avoid indentation, use the `\noindent` command.
2. Note the `\usepackage` command which changes the font and invokes the AMS mathematics commands (which simplify typesetting). Note the use of the `\thispagestyle{empty}` command to avoid the printing of page number on the title page.
3. Use L^AT_EX commands carefully. Please review how to use math mode. Many of the reports had math in the text that was not in math mode. All symbols, variable, and so on are to be written in math mode. We do not use computer science variables to write equations, either, thus

$$\overset{upperbound}{\sum_{i=1}} x_i^2$$

is not acceptable, while

$$\sum_{i=1}^n x_i^2$$

is acceptable.

4. There is no need for asterices in multiplication. Thus ab or xy , not $a * b$ or $x * y$.
5. Please note that L^AT_EX uses the forward and backward quotes. Thus we write “*This is a quote*”, and not “*This is a quote*”. Examine this example closely. The forward quote is written using the ‘ and not the ’ quote. The forward quote is typically on the upper left of your keyboard, on the tilde key, and below the Esc key.

2.1.1 Background on technical writing

Introduce the mathematical ideas and how they are implemented in this section. You should not have any results here. Only introduce the mathematics that is necessary to discuss your results. For example, the method used to compute each norm may be important, however you may choose to either typeset the equations or refer to these in your text, or any other reference. You may refer to equations using a bibliography reference generated using a bib file.

2.1.2 What’s in the Results

Discuss the results. This means that you provide details concerning the numerical experiments that were performed. This section should include graphs, tables and other supporting

documentation. It should read well, and all items discussed in the text should refer to tables, graphs and equations using the reference command in L^AT_EX and using the format `Table~\ref{table:mytable}`, `Figure~\ref{figure:myfigure}` to refer to tables and figures. Equations should be referred to using the number of the equation in parentheses, i.e., `(\ref{eq:myequation})`. You never use the word ‘equation’, except at the beginning of a sentence, in which case you use the construction: `Eq.~(\ref{eq:myequation})`. Note that you need the `~`, i.e., the tilde, to avoid having L^AT_EX break the object across a line. Always tie counters to their attributes using a tilde or a thin space, e.g.,

tied using a tilde: `in Sec.~\ref{sec:topics} ⇒ in Sec. 3.7`

tied using a thin space: `in Sec.\, \ref{sec:topics} ⇒ in Sec. 3.7`

untied (wrong): `in Sec. \ref{sec:topics} ⇒ in Sec. 3.7`

which ties the object `Sec.` to the counter. Not only is the space too large after the period when there is no tie, but there is the danger that the word, `Sec.`, will go at the end of one line, and the number `3.7` at the start of a new line.

When doing numerical studies, you must present the results of all of your numerical investigations. For the case of polynomial interpolation, at the very least these results should have examined the behaviour of the polynomials interpolated on 2^k points, where $k = 2, 3, \dots, n$, where n is sufficiently large so as to be able to determine numerically whether convergence was achieved. A value of $n = 5$, or $n = 10$ is usually insufficient.

Focus on the error. Numerical methods are approximations. They introduce error. Examine the errors, and attempt to understand where they are coming from. Examine issues of computational efficiency, and other topics as appropriate. Time your results when you run the codes. You can always choose not to use the timing results, however if they show something important, then you can use it.

2.1.3 What’s in the Conclusion

Be brief, however one sentence is not sufficient. Try to concisely summarize what was discussed in the results. Avoid rewriting the results section. Someone reading your report should be able to understand the writeup from what is written in this section. This is one of the most important parts of your report (and probably the only one your supervisor or manager will ever read, so you might as well learn to write it effectively).

2.1.4 Using an Appendix

If there are details concerning the code which you wrote which are significant and pertain to the discussion, place these here. While we are on the topic of codes and software, please put

your code variables into `\tt` font, e.g.,

Acceptable style:

We used the value of NumMax to determine the degree of the polynomial ...

Unacceptable style:

We used the value of **NumMax** to determine the degree of the polynomial ...

Write all code segments that are discussed using the same method, and use the verbatim environment, i.e.,

```
ofstream outfile;  
outfile.open(names, ios::app);
```

as this will prevent the code from being typeset as ordinary text. There are special ways of inputting code that also can be used, and these are described in detail in the appendices. We can link to these conveniently within L^AT_EX using reference and label commands. For example, we can go to Appendix A, Appendix B, Appendix C, or Appendix D using the `\label{}` command to label an environment and using the `\ref{}` command to refer to it in the text.

As an ending note, use the `math-preamble.tex` file to define commonly used math objects. For example, in typing $\frac{3}{4}$ we did not have to enter math mode to get the fraction displayed as we used the `\ensuremath` command to ensure that it was in math mode. The user's ability to define macros, such as

```
\newcommand{\vfrac}[2]{\ensuremath{\frac{#1}{#2}}}
```

is one of the enormous strengths of L^AT_EX. Instead of constantly having to type

```
\ensuremath{\frac{a}{b}}
```

the user can now type

```
\vfrac{a}{b}
```

to get the same result, $\frac{a}{b}$.

Chapter 3

Working with fonts

3.1 Some Useful Fonts

These symbols, like ¶, §, †, and ‡, can also be used in math mode, and will change sizes correctly in subscripts and superscripts. The Blackboard Bold letters $\mathbb{A}, \dots, \mathbb{Z}$ can be accessed by typing (in math mode). Additional symbols of interest include ■, ►, ★, and ✓. To get bold in math use command `\boldsymbol`, $x, y, f(x)$.



Signs that text is the medium of the page. In the example used to start a page with a large letter S, the example illustrates the use of the kern command and the font command to select a font directly with a scaling factor:

Some other fonts of utility include the fractur fonts, which can be called directly using T_EX commands (in various sizes):

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z

The color for the dropdown font is chosen with the `\textcolor{}` command. There are quite a range of colors that can be accessed, as described in Appendix D. They can also be custom constructed, i.e., there is no practical limit on the color range.

Letters in the eufm font can be accessed (in math mode) by typing, for example, `\frac A` or `\frac g` to get $\mathfrak{A}g$. For the other Euler fonts, see the various “Euler” subsections under the sections for different macro packages (L^AT_EX, plain T_EX). The math calligraphic letters are modified from the standard ones in latex by using the `euca1.sty` package. These yield, $ABCDEFGHIJKL MNOPQRSTUVWXYZ$.

Do not over do the fonts. If there are too many font changes, the text becomes difficult

to read, however, some worthwhile font selections include the use of the small caps font to head a small section:

3.2 Scaling fonts in math

Scaling integrals:

- The standard way to scale a font of an image, is to use the `\scalebox` command which is part of the `graphicx` package, using for example

```
{\large E\scalebox{0.7}{EDUCATION}}
```

to get the letter E to be larger than the other letters in the word,

EDUCATION

This does not work in math mode, though. In math mode there are techniques available for scaling the size of the text that is displayed. The most common of these is to use the command `\displaystyle` to put math into display mode. For example:

- The standard integral is given by:

$$\int_a^b f(x)dx.$$

- The integral using `\displaystyle`:

$$\int_a^b f(x)dx.$$

- The integral using `\displaystyle` with the `\mathlarger` command from the `relsize` package:

$$\int_a^b f(x)dx.$$

- The integral using `\displaystyle` with the `\bigintsss` command from the `bigint` package:

$$\int_a^b f(x)dx.$$

- The integral using `\displaystyle` with the `\bigintss` command from the `bigint` package:

$$\int_a^b f(x)dx.$$

- The integral using `\displaystyle` with the `\bigints` command from the `bigint` package:

$$\int_a^b f(x)dx.$$

- The integral using `\displaystyle` with the `\bigint` command from the `bigint` package:

$$\int_a^b f(x)dx.$$

- You can of course, place the limits on top and bottom of the integral using the `\limits` command, however it will have to be adjusted for the `\bigint` type commands:

$$\int_a^b f(x)dx, \quad \int_a^b f(x)dx.$$

3.3 Using different fonts

This section explores setting fonts dynamically using the

`\usefont{T1}{FAMILY}{m}{n}\fontsize{F}{S}\selectfont` command, where `F` is the font size and `S` is the font spacing, and `FAMILY` is the code for the font family. In these examples, the font family and the font name are give before some text generated using that font family.

ptm Times

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Imss Latin Modern Sans

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Additional resources

The L^AT_EX Font Catalogue at <http://www.tug.dk/FontCatalogue/> is a start.

Chapter 4

Working with math

4.1 AMS Introduction

This paper contains examples of various features from $\mathcal{A}\mathcal{M}\mathcal{S}$ - $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ and was abstracted from the file `testmath.tex`. The citations have been removed.

4.2 Enumeration of Hamiltonian Paths in a Graph

Let $\mathbf{A} = (a_{ij})$ be the adjacency matrix of graph G . The corresponding Kirchhoff matrix $\mathbf{K} = (k_{ij})$ is obtained from \mathbf{A} by replacing in $-\mathbf{A}$ each diagonal entry by the degree of its corresponding vertex; i.e., the i th diagonal entry is identified with the degree of the i th vertex. It is well known that

$$\det \mathbf{K}(i|i) = \text{the number of spanning trees of } G, \quad i = 1, \dots, n \quad (4.1)$$

where $\mathbf{K}(i|i)$ is the i th principal submatrix of \mathbf{K} .

$\det \mathbf{K}(i|i) = \text{the number of spanning trees of } G$,

Let $C_{i(j)}$ be the set of graphs obtained from G by attaching edge $(v_i v_j)$ to each spanning tree of G . Denote by $C_i = \bigcup_j C_{i(j)}$. It is obvious that the collection of Hamiltonian cycles is a subset of C_i . Note that the cardinality of C_i is $k_{ii} \det \mathbf{K}(i|i)$. Let $X = \{\hat{x}_1, \dots, \hat{x}_n\}$.

$X = \{\hat{x}_1, \dots, \hat{x}_n\}$

Define multiplication for the elements of X by

$$\hat{x}_i \hat{x}_j = \hat{x}_j \hat{x}_i, \quad \hat{x}_i^2 = 0, \quad i, j = 1, \dots, n. \quad (4.2)$$

Let $\hat{k}_{ij} = k_{ij} \hat{x}_j$ and $\hat{k}_{ji} = -\sum_{j \neq i} \hat{k}_{ij}$. Then the number of Hamiltonian cycles H_c is given by the relation

$$\left(\prod_{j=1}^n \hat{x}_j \right) H_c = \frac{1}{2} \hat{k}_{ij} \det \mathbf{K}(i|i), \quad i = 1, \dots, n. \quad (4.3)$$

The task here is to express (4.3) in a form free of any \hat{x}_i , $i = 1, \dots, n$. The result also leads to the resolution of enumeration of Hamiltonian paths in a graph.

It is well known that the enumeration of Hamiltonian cycles and paths in a complete graph K_n and in a complete bipartite graph $K_{n_1 n_2}$ can only be found from *first combinatorial principles*. One wonders if there exists a formula which can be used very efficiently to produce K_n and $K_{n_1 n_2}$. Recently, using Lagrangian methods, Goulden and Jackson have shown that H_c can be expressed in terms of the determinant and permanent of the adjacency matrix. However, the formula of Goulden and Jackson determines neither K_n nor $K_{n_1 n_2}$ effectively. In this paper, using an algebraic method, we parametrize the adjacency matrix. The resulting formula also involves the determinant and permanent, but it can easily be applied to K_n and $K_{n_1 n_2}$. In addition, we eliminate the permanent from H_c and show that H_c can be represented by a determinantal function of multivariables, each variable with domain $\{0, 1\}$. Furthermore, we show that H_c can be written by number of spanning trees of subgraphs. Finally, we apply the formulas to a complete multigraph $K_{n_1 \dots n_p}$.

The conditions $a_{ij} = a_{ji}$, $i, j = 1, \dots, n$, are not required in this paper. All formulas can be extended to a digraph simply by multiplying H_c by 2.

4.3 Application

We consider here the applications of these Theorems to a complete multipartite graph $K_{n_1 \dots n_p}$. It can be shown that the number of spanning trees of $K_{n_1 \dots n_p}$ may be written

$$T = n^{p-2} \prod_{i=1}^p (n - n_i)^{n_i-1} \quad (4.4)$$

where

$$n = n_1 + \dots + n_p. \quad (4.5)$$

It follows that

$$H_c = \frac{1}{2n} \sum_{l=0}^n (-1)^l (n-l)^{p-2} \sum_{l_1 + \dots + l_p = l} \prod_{i=1}^p \binom{n_i}{l_i} \cdot [(n-l) - (n_i - l_i)]^{n_i - l_i} \cdot \left[(n-l)^2 - \sum_{j=1}^p (n_i - l_i)^2 \right]. \quad (4.6)$$

... \binom{n_i}{l_i} \\

and

$$H_c = \frac{1}{2} \sum_{l=0}^{n-1} (-1)^l (n-l)^{p-2} \sum_{l_1 + \dots + l_p = l} \prod_{i=1}^p \binom{n_i}{l_i} \cdot [(n-l) - (n_i - l_i)]^{n_i - l_i} \left(1 - \frac{l_p}{n_p} \right) [(n-l) - (n_p - l_p)]. \quad (4.7)$$

The enumeration of H_c in a $K_{n_1 \dots n_p}$ graph can also be carried out by these theorems together with the algebraic method of (4.2). Some elegant representations may be obtained. For example, H_c in a $K_{n_1 n_2 n_3}$ graph may be written

$$H_c = \frac{n_1! n_2! n_3!}{n_1 + n_2 + n_3} \sum_i \left[\binom{n_1}{i} \binom{n_2}{n_3 - n_1 + i} \binom{n_3}{n_3 - n_2 + i} + \binom{n_1 - 1}{i} \binom{n_2 - 1}{n_3 - n_1 + i} \binom{n_3 - 1}{n_3 - n_2 + i} \right]. \quad (4.8)$$

4.4 Secret Key Exchanges

Modern cryptography is fundamentally concerned with the problem of secure private communication. A Secret Key Exchange is a protocol where Alice and Bob, having no secret information in common to start, are able to agree on a common secret key, conversing over a public channel. The notion of a Secret Key Exchange protocol was first introduced in the seminal paper of Diffie and Hellman which presented a concrete implementation of a Secret Key Exchange protocol, dependent on a specific assumption (a variant on the discrete log), specially tailored to yield Secret Key Exchange. Secret Key Exchange is of course trivial if trapdoor permutations exist. However, there is no known implementation based on a weaker general assumption.

Chapter 5

Results

5.1 Super results

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5.2 Using figures

We demonstrate a technique to set up and configure a figure using the `\includegraphics` command embedded into the `picture` environment embedded into the `figure` environment. The `picture` environment is needed to control the spacing, while the `figure` environment is needed to control the floating of the figures in the document. Note that you can refer to the figure with its label, i.e., in Figure 5.2 you have the setup of the figure. Note that you need to create the figures so that the labels and legends scale well with the fonts being used after you have scaled the figure. The examples in Fig. 5.1 and Fig. 5.2 should be examined in detail as the axes labels are not generated with the figures. Instead, they are added as overlays using the `\put` command in the `picture` environment.

Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetur at, consectetur sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

Morbi luctus, wisi viverra faucibus pretium, nibh est placerat odio, nec commodo wisi enim eget quam. Quisque libero justo, consectetur a, feugiat vitae, porttitor eu, libero.

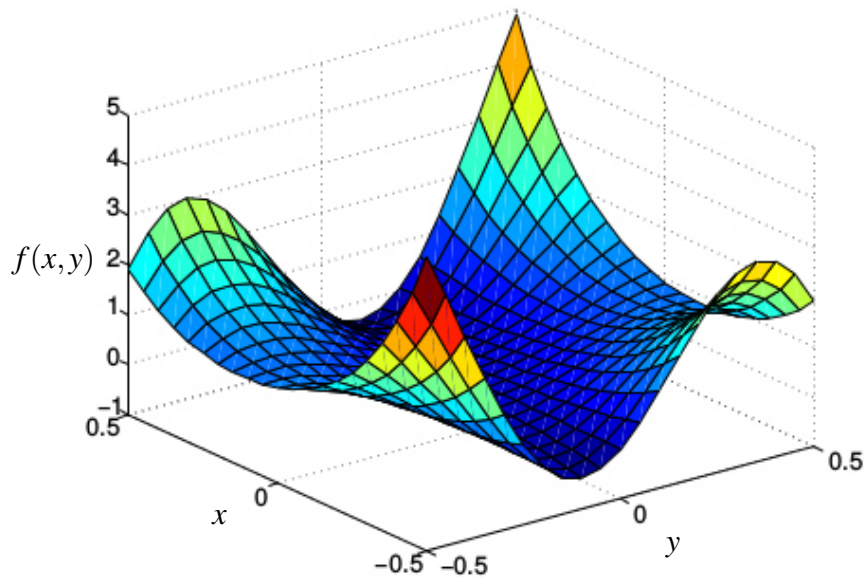


Figure 5.1: Example of using a raster image which is scaled and annotated with axes.

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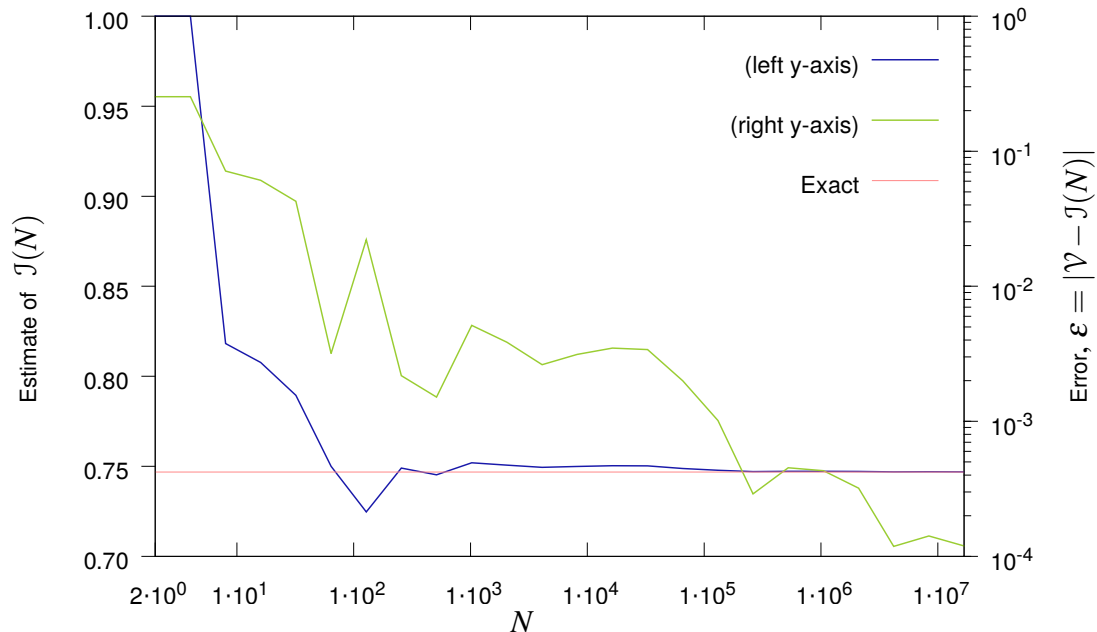


Figure 5.2: An approximation $J(N)$ to the value of the integral for $\int_0^1 e^{x^2} dx$ obtained using a Monte Carlo approach. The estimate for $J(N)$ is a function of the number of samples N , and the value of $I \approx 0.7468241328 \equiv \mathcal{V}$ was obtained using Wolfram Alpha[®].

5.3 Using another figure

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

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i	1	2	3	4	5	6	7
P_i	0.34	0.11	0.11	0.11	0.11	0.11	0.11
$l(P)$	1	2	2	2	2	2	2
$\text{code}(P)$	0	10	11	12	20	21	22
Ideal Length	0.982	2.009	2.009	2.009	2.009	2.009	2.009

Table 5.1: Tabulated results in base 3 with actual and ideal code length.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

An alternative style of table is present in which the fonts are fixed spacing and the rows are alternately colored to improve readability.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam

N	$\mathcal{J}(N)$	Error, ϵ
2	1.00000000	0.25317587
4	1.00000000	0.25317587
8	0.81818182	0.07135769
16	0.80769231	0.06086817
32	0.78947368	0.04264955
64	0.75000000	0.00317587
128	0.72469636	0.02212778
256	0.74900398	0.00217985
512	0.74531096	0.00151318
1024	0.75196464	0.00514050
2048	0.75067352	0.00384939
4096	0.74944974	0.00262561
8192	0.74995418	0.00313005
16384	0.75030532	0.00348119
32768	0.75022513	0.00340099
65536	0.74882110	0.00199696
131072	0.74783786	0.00101373
262144	0.74711407	0.00028994
524288	0.74727697	0.00045283
1048576	0.74725506	0.00043093
2097152	0.74714403	0.00031989
4194304	0.74694263	0.00011850
8388608	0.74696581	0.00014167
16777216	0.74694349	0.00011935

Table 5.3: Data generated using the code, `monte.py`. The output in this table is generated by `monte-latex.py` which has \LaTeX formatting included. This table illustrates the use of color, and while color is typically not used in most journal publications, it does provide a means of making reports and other online articles more readable. In this example the use of a custom font is also illustrated.

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felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed
a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus
sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus
enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas
wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

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nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu
purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit
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ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas
vel, odio.

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hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse
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odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat
ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin
et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos
hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

5.4 Even more results

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enim eget quam. Quisque libero justo, consectetur a, feugiat vitae, porttitor eu, libero.
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ante. Ut venenatis velit. Maecenas sed mi eget dui varius euismod. Phasellus aliquet
volutpat odio. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere
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tristique arcu eu metus. Vestibulum lectus. Proin mauris. Proin eu nunc eu urna hendrerit
faucibus. Aliquam auctor, pede consequat laoreet varius, eros tellus scelerisque quam,
pellentesque hendrerit ipsum dolor sed augue. Nulla nec lacus.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo
eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et,
lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo.
Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas

imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consectetuer odio sem sed wisi.

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Chapter 6

Conclusions and Future Work

6.1 Known Results

Everything we have done is completely correct based on the theory of everything. Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis consetetur tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

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Etiam ac leo a risus tristique nonummy. Donec dignissim tincidunt nulla. Vestibulum rhoncus molestie odio. Sed lobortis, justo et pretium lobortis, mauris turpis condimentum augue, nec ultricies nibh arcu pretium enim. Nunc purus neque, placerat id, imperdiet sed, pellentesque nec, nisl. Vestibulum imperdiet neque non sem accumsan laoreet. In hac habitasse platea dictumst. Etiam condimentum facilisis libero. Suspendisse in elit quis nisl aliquam dapibus. Pellentesque auctor sapien. Sed egestas sapien nec lectus. Pellentesque vel dui vel neque bibendum viverra. Aliquam porttitor nisl nec pede. Proin mattis libero vel turpis. Donec rutrum mauris et libero. Proin euismod porta felis. Nam lobortis, metus quis elementum commodo, nunc lectus elementum mauris, eget vulputate ligula tellus eu neque. Vivamus eu dolor.

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tincidunt. Curabitur eros ligula, varius ut, pulvinar in, cursus faucibus, augue.

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6.2 Wrapup

Where can we find information about this thesis style? Go to <http://math.newhaven.edu/mathphysics>.

Appendices

Appendix A

Software listings

A.1 Code listing

In Appendices A, B, C, D we examine several methods for including software listings into \LaTeX . The method used in this appendix is the most complex approach using the python script, pygmentize, which allows for a full range of options, however the resulting text that is generated is not the actual code, but mostly markups of the code that make it very difficult to read from the \LaTeX source itself. Compare the source files, chap-appendixa.tex and chap-appendixb.tex for the code monte.py to view the difference. The advantage to using pygmentize which is part of the Pygments software package at <http://pygments.org/> is that it is a cross-platform python based syntax highlighter that can produce output in any of several output formats, including \LaTeX and HTML, and it can work with an enormously wide range of input formats.

```
#!/usr/bin/python
from random import *
from math import sqrt, exp
fo=open('data.dat','w')

INT=0.7468241328
M=25
N=1
hits = 0
throws = 0
seed(2303417331)
for j in range (1, M):
    N=2*N
    for i in range (1, N):
        throws += 1
        x = random()
        y = random()
        f = exp(-x*x)
        if y <= f:
            hits = hits + 1.0
    area = (hits / throws)
    error = abs(area - INT)
    print ("{0:8d} {1:.8f} {2:.8f}".format(N, area, error))
    print >> fo, ("{0:8d} {1:.8f} {2:.8f}".format(N, area, error))

fo.close
```

Appendix B

More software listings

B.1 Another Code listing

This is the most foundational method, consisting of a verbatim listing of the code wrapped around a coloring of the text to make it stand out from the other text on the page.

Code listing for `monte.py`

```
#!/usr/bin/python
from random import *
from math import sqrt, exp
fo=open('data.dat','w')

INT=0.7468241328
M=25
N=1
hits = 0
throws = 0
seed(2303417331)
for j in range (1, M):
N=2*N
for i in range (1, N):
throws += 1
x = random()
y = random()
f = exp(-x*x)
if y <= f:
hits = hits + 1.0
area = (hits / throws)
error = abs(area - INT)
print ("{0:8d} {1:.8f} {2:.8f}".format(N, area, error))
print >> fo, ("{0:8d} {1:.8f} {2:.8f}".format(N, area, error))

fo.close
```

Code listing for `monte-latex.py`

```
#!/usr/bin/python
from random import *
from math import sqrt, exp
ft=open('data.tex','w')
fo=open('data.dat','w')

INT=0.7468241328
M=25
N=1
hits = 0
throws = 0
seed(73417331)
print >> ft, ("{\usefont{T1}{jkptt}{m}{n}\fontsize{9.0}{10.8}\selectfont")
print >> ft, ("{\begin{longtable}{|r|r|r|}")
print >> ft, ("{\hline")
```

```

print >> ft, ("$$ & $\{cal I\}(N)$ \
  \hspace*{0.8em} & \textbf{\Hf Error}, $\varepsilon$ \hspace*{0.2em} \\\")
print >> ft, ("\\hline")
for j in range (1, M):
  N=2*N
  for i in range (1, N):
    throws += 1
    x = random()
    y = random()
    f = exp(-x*x)
    if y <= f:
      hits = hits + 1.0
  area = (hits / throws)
  error = abs(area - INT)
  print ("{0:8d} {1:.8f} {2:.8f}".format(N, area, error))
  print >> fo, ("{0:8d} {1:.8f} {2:.8f}".format(N, area, error))
  print >> ft, ("{0:8d} & {1:.8f} & {2:.8f} \\\").format(N, area, error))
  # f.write("{0:8d} {1:.8f} {2:.8f}" % (N, area, error))

print >> ft, ("\\hline")
print >> ft, ("\\end{longtable}")
fo.close
ft.close

```

Appendix C

Another approach to software listings

C.1 Still another way of listing

This method uses the `listings` package to provide a means of listing software. The advantage over using `pygmentize` is that the code is actually readable, while the text generated by `pygmentize` is not readable. Also, packages usually have quite a range of options that can be customized.

```

1 public class Hello
2 {
3     public static void main(String[] args)
4     {
5         // print hello to the console
6         System.out.println("Hello, world!");
7     }
8 }

```

Listing C.1: Java code using listings.

```

1 from random import random
2 from math import sqrt, exp
3
4 INT=0.7468241328
5 M=25
6 N=1
7 hits = 0
8 throws = 0
9 for j in range (1, M):
10     N=2*N
11     for i in range (1, N):
12         throws += 1
13         x = random()
14         y = random()
15         f = exp(-x*x)
16         if y <= f:
17             hits = hits + 1.0
18     area = (hits / throws)
19     error = abs(area - INT)
20     # print " area = %s" %(area)
21     print (" {0:8d} {1:.8f} {2:.8f}".format(N, area, error))

```

Listing C.2: Python code using listings.

```
1 #include <iostream>
2 int main()
3 {
4     // print hello to the console
5     std::cout << "Hello, world!" << std::endl;
6     return 0;
7 }
```

Listing C.3: C++ code using listings.

Appendix D

Color names

D.1 The `xcolor` color names

The next few pages lists all of the colors provided when the color options used by the `xcolor` LaTeX package. This list is taken from the `xcolor` package documentation and is intended to be used as a reference for selecting a color to use within templates.

It is also worth noting that the pages that are included in this appendix are pulled in from a pdf file using the command,

```
\includepdf[pages={1-3}, nup={1x1},scale={0.9},delta={0.0pt 0.0pt}]  
  {figures/xcolors.pdf}
```




















This is an essential and valuable package, however it breaks the `hyperref` package, and so links are not possible on these pages.

xcolor v2.11 (2007/01/21)

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4 Colors by Name

4.1 Base colors (always available)





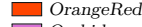
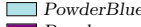

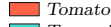


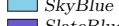
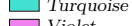
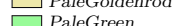

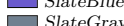

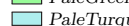
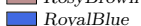
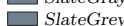
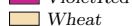
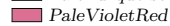
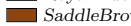
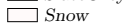
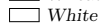
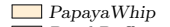
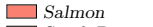


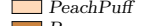

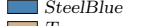
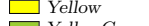
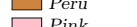
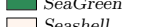
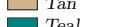
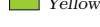

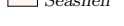





 black	 darkgray	 lime	 pink	 violet
 blue	 gray	 magenta	 purple	 white
 brown	 green	 olive	 red	 yellow
 cyan	 lightgray	 orange	 teal	

4.2 Colors via dvipsnames option

 Apricot	 Cyan	 Mahogany	 ProcessBlue	 SpringGreen
 Aquamarine	 Dandelion	 Maroon	 Purple	 Tan
 Bittersweet	 DarkOrchid	 Melon	 RawSienna	 TealBlue
 Black	 Emerald	 MidnightBlue	 Red	 Thistle
 Blue	 ForestGreen	 Mulberry	 RedOrange	 Turquoise
 BlueGreen	 Fuchsia	 NavyBlue	 RedViolet	 Violet
 BlueViolet	 Goldenrod	 OliveGreen	 Rhodamine	 VioletRed
 BrickRed	 Gray	 Orange	 RoyalBlue	 White
 Brown	 Green	 OrangeRed	 RoyalPurple	 WildStrawberry
 BurntOrange	 GreenYellow	 Orchid	 RubineRed	 Yellow
 CadetBlue	 JungleGreen	 Peach	 Salmon	 YellowGreen
 CarnationPink	 Lavender	 Periwinkle	 SeaGreen	 YellowOrange
 Cerulean	 LimeGreen	 PineGreen	 Sepia	
 CornflowerBlue	 Magenta	 Plum	 SkyBlue	

4.3 Colors via svgnames option

 AliceBlue	 DarkKhaki	 Green	 LightSlateGrey
 AntiqueWhite	 DarkMagenta	 GreenYellow	 LightSteelBlue
 Aqua	 DarkOliveGreen	 Grey	 LightYellow
 Aquamarine	 DarkOrange	 Honeydew	 Lime
 Azure	 DarkOrchid	 HotPink	 LimeGreen
 Beige	 DarkRed	 IndianRed	 Linen
 Bisque	 DarkSalmon	 Indigo	 Magenta
 Black	 DarkSeaGreen	 Ivory	 Maroon
 BlanchedAlmond	 DarkSlateBlue	 Khaki	 MediumAquamarine
 Blue	 DarkSlateGray	 Lavender	 MediumBlue
 BlueViolet	 DarkSlateGrey	 LavenderBlush	 MediumOrchid
 Brown	 DarkTurquoise	 LawnGreen	 MediumPurple
 BurlyWood	 DarkViolet	 LemonChiffon	 MediumSeaGreen
 CadetBlue	 DeepPink	 LightBlue	 MediumSlateBlue
 Chartreuse	 DeepSkyBlue	 LightCoral	 MediumSpringGreen
 Chocolate	 DimGray	 LightCyan	 MediumTurquoise
 Coral	 DimGrey	 LightGoldenrod	 MediumVioletRed
 CornflowerBlue	 DodgerBlue	 LightGoldenrodYellow	 MidnightBlue
 Cornsilk	 FireBrick	 LightGray	 MintCream
 Crimson	 FloralWhite	 LightGreen	 MistyRose
 Cyan	 ForestGreen	 LightGrey	 Moccasin
 DarkBlue	 Fuchsia	 LightPink	 NavajoWhite
 DarkCyan	 Gainsboro	 LightSalmon	 Navy
 DarkGoldenrod	 GhostWhite	 LightSeaGreen	 NavyBlue
 DarkGray	 Gold	 LightSkyBlue	 OldLace
 DarkGreen	 Goldenrod	 LightSlateBlue	 Olive
 DarkGrey	 Gray	 LightSlateGray	 OliveDrab


























































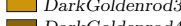



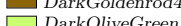



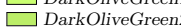







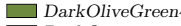



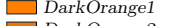



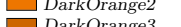
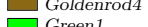


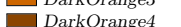
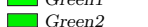


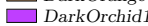
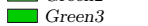


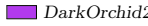



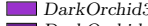



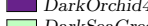



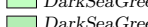



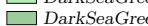



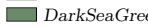



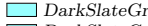



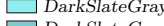



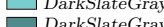



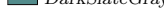






















 Orange	 Plum	 Sienna	 Thistle
 OrangeRed	 PowderBlue	 Silver	 Tomato
 Orchid	 Purple	 SkyBlue	 Turquoise
 PaleGoldenrod	 Red	 SlateBlue	 Violet
 PaleGreen	 RosyBrown	 SlateGray	 VioletRed
 PaleTurquoise	 RoyalBlue	 SlateGrey	 Wheat
 PaleVioletRed	 SaddleBrown	 Snow	 White
 PapayaWhip	 Salmon	 SpringGreen	 WhiteSmoke
 PeachPuff	 SandyBrown	 SteelBlue	 Yellow
 Peru	 SeaGreen	 Tan	 YellowGreen
 Pink	 Seashell	 Teal	

Duplicate colors: Aqua = Cyan, Fuchsia = Magenta; Navy = NavyBlue; Gray = Grey, DarkGray = DarkGrey, LightGray = LightGrey, SlateGray = SlateGrey, DarkSlateGray = DarkSlateGrey, LightSlateGray = LightSlateGrey, DimGray = DimGrey.

HTML4 color keyword subset: Aqua, Black, Blue, Fuchsia, Gray, Green, Lime, Maroon, Navy, Olive, Purple, Red, Silver, Teal, White, Yellow.






































































































































































Colors taken from Unix/X11: LightGoldenrod, LightSlateBlue, NavyBlue, VioletRed.

4.4 Colors via x11names option

 AntiqueWhite1	 Chocolate3	 DeepPink1	 IndianRed3
 AntiqueWhite2	 Chocolate4	 DeepPink2	 IndianRed4
 AntiqueWhite3	 Coral1	 DeepPink3	 Ivory1
 AntiqueWhite4	 Coral2	 DeepPink4	 Ivory2
 Aquamarine1	 Coral3	 DeepSkyBlue1	 Ivory3
 Aquamarine2	 Coral4	 DeepSkyBlue2	 Ivory4
 Aquamarine3	 Cornsilk1	 DeepSkyBlue3	 Khaki1
 Aquamarine4	 Cornsilk2	 DeepSkyBlue4	 Khaki2
 Azure1	 Cornsilk3	 DodgerBlue1	 Khaki3
 Azure2	 Cornsilk4	 DodgerBlue2	 Khaki4
 Azure3	 Cyan1	 DodgerBlue3	 LavenderBlush1
 Azure4	 Cyan2	 DodgerBlue4	 LavenderBlush2
 Bisque1	 Cyan3	 Firebrick1	 LavenderBlush3
 Bisque2	 Cyan4	 Firebrick2	 LavenderBlush4
 Bisque3	 DarkGoldenrod1	 Firebrick3	 LemonChiffon1
 Bisque4	 DarkGoldenrod2	 Firebrick4	 LemonChiffon2
 Blue1	 DarkGoldenrod3	 Gold1	 LemonChiffon3
 Blue2	 DarkGoldenrod4	 Gold2	 LemonChiffon4
 Blue3	 DarkOliveGreen1	 Gold3	 LightBlue1
 Blue4	 DarkOliveGreen2	 Gold4	 LightBlue2
 Brown1	 DarkOliveGreen3	 Goldenrod1	 LightBlue3
 Brown2	 DarkOliveGreen4	 Goldenrod2	 LightBlue4
 Brown3	 DarkOrange1	 Goldenrod3	 LightCyan1
 Brown4	 DarkOrange2	 Goldenrod4	 LightCyan2
 Burlywood1	 DarkOrange3	 Green1	 LightCyan3
 Burlywood2	 DarkOrange4	 Green2	 LightCyan4
 Burlywood3	 DarkOrchid1	 Green3	 LightGoldenrod1
 Burlywood4	 DarkOrchid2	 Green4	 LightGoldenrod2
 CadetBlue1	 DarkOrchid3	 Honeydew1	 LightGoldenrod3
 CadetBlue2	 DarkOrchid4	 Honeydew2	 LightGoldenrod4
 CadetBlue3	 DarkSeaGreen1	 Honeydew3	 LightPink1
 CadetBlue4	 DarkSeaGreen2	 Honeydew4	 LightPink2
 Chartreuse1	 DarkSeaGreen3	 HotPink1	 LightPink3
 Chartreuse2	 DarkSeaGreen4	 HotPink2	 LightPink4
 Chartreuse3	 DarkSlateGray1	 HotPink3	 LightSalmon1
 Chartreuse4	 DarkSlateGray2	 HotPink4	 LightSalmon2
 Chocolate1	 DarkSlateGray3	 IndianRed1	 LightSalmon3
 Chocolate2	 DarkSlateGray4	 IndianRed2	 LightSalmon4

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 LightSkyBlue1	 Orange3	 RosyBrown1	 SpringGreen3
 LightSkyBlue2	 Orange4	 RosyBrown2	 SpringGreen4
 LightSkyBlue3	 OrangeRed1	 RosyBrown3	 SteelBlue1
 LightSkyBlue4	 OrangeRed2	 RosyBrown4	 SteelBlue2
 LightSteelBlue1	 OrangeRed3	 RoyalBlue1	 SteelBlue3
 LightSteelBlue2	 OrangeRed4	 RoyalBlue2	 SteelBlue4
 LightSteelBlue3	 Orchid1	 RoyalBlue3	 Tan1
 LightSteelBlue4	 Orchid2	 RoyalBlue4	 Tan2
 LightYellow1	 Orchid3	 Salmon1	 Tan3
 LightYellow2	 Orchid4	 Salmon2	 Tan4
 LightYellow3	 PaleGreen1	 Salmon3	 Thistle1
 LightYellow4	 PaleGreen2	 Salmon4	 Thistle2
 Magenta1	 PaleGreen3	 SeaGreen1	 Thistle3
 Magenta2	 PaleGreen4	 SeaGreen2	 Thistle4
 Magenta3	 PaleTurquoise1	 SeaGreen3	 Tomato1
 Magenta4	 PaleTurquoise2	 SeaGreen4	 Tomato2
 Maroon1	 PaleTurquoise3	 Seashell1	 Tomato3
 Maroon2	 PaleTurquoise4	 Seashell2	 Tomato4
 Maroon3	 PaleVioletRed1	 Seashell3	 Turquoise1
 Maroon4	 PaleVioletRed2	 Seashell4	 Turquoise2
 MediumOrchid1	 PaleVioletRed3	 Sienna1	 Turquoise3
 MediumOrchid2	 PaleVioletRed4	 Sienna2	 Turquoise4
 MediumOrchid3	 PeachPuff1	 Sienna3	 VioletRed1
 MediumOrchid4	 PeachPuff2	 Sienna4	 VioletRed2
 MediumPurple1	 PeachPuff3	 SkyBlue1	 VioletRed3
 MediumPurple2	 PeachPuff4	 SkyBlue2	 VioletRed4
 MediumPurple3	 Pink1	 SkyBlue3	 Wheat1
 MediumPurple4	 Pink2	 SkyBlue4	 Wheat2
 MistyRose1	 Pink3	 SlateBlue1	 Wheat3
 MistyRose2	 Pink4	 SlateBlue2	 Wheat4
 MistyRose3	 Plum1	 SlateBlue3	 Yellow1
 MistyRose4	 Plum2	 SlateBlue4	 Yellow2
 NavajoWhite1	 Plum3	 SlateGray1	 Yellow3
 NavajoWhite2	 Plum4	 SlateGray2	 Yellow4
 NavajoWhite3	 Purple1	 SlateGray3	 Gray0
 NavajoWhite4	 Purple2	 SlateGray4	 Green0
 OliveDrab1	 Purple3	 Snow1	 Grey0
 OliveDrab2	 Purple4	 Snow2	 Maroon0
 OliveDrab3	 Red1	 Snow3	 Purple0
 OliveDrab4	 Red2	 Snow4	
 Orange1	 Red3	 SpringGreen1	
 Orange2	 Red4	 SpringGreen2	

Duplicate colors: Gray0 = Grey0, Green0 = Green1.

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