Portions Copyright (c) 2005 Timothy Daly

The Blue Bayou image Copyright (c) 2004 Jocelyn Guidry

Portions Copyright (c) 2004 Martin Dunstan
Portions Copyright (c) 2007 Alfredo Portes
Portions Copyright (c) 2007 Arthur Ralfs
Portions Copyright (c) 2005 Timothy Daly

Portions Copyright (c) 1991-2002,
The Numerical ALgorithms Group Ltd.
All rights reserved.

This book and the Axiom software is licensed as follows:

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

- Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.

- Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.

- Neither the name of The Numerical ALgorithms Group Ltd. nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
Inclusion of names in the list of credits is based on historical information and is as accurate as possible. Inclusion of names does not in any way imply an endorsement but represents historical influence on Axiom development.

Michael Albaugh  
Christian Aistleitner  
S.J. Atkins  
Stephen Balzac  
Gerald Baumgartner  
Nelson H. F. Beebe  
Fred Blair  
Raoul Bourquin  
Peter A. Broadbery  
Stephen Buchwald  
William Burge  
Robert Caviness  
Tzu-Yi Chen  
Gregory V. Chudnovsky  
Jia Zhao Cong  
Don Coppersmith  
Gary Cornell  
David Cyganski  
Timothy Daly Jr.  
James Demmel  
Jack Dongarra  
Claire DiCrescendo  
Iain Duff  
Brian Dupee  
Heow Eide-Goodman  
Bertfried Fauser  
Brian Ford  
Constantine Frangos  
Marc Gaetano  
Kathy Gerber  
Holger Gollan  
Stephen Gortler  
Klaus Ebbe Grue  
Oswald Gschnitzer  
Gaetan Hache  
Sven Hammarling  
Richard Harke  
Martin Hassner  
Waldek Hebisch  
Cyril Alberga  
Richard Anderson  
Henry Baker  
Yuri Baransky  
Gilbert Baumslag  
Jay Belanger  
Vladimir Bondarenko  
Alexandre Bouyer  
Martin Brock  
Florian Bundschuh  
Ralph Byers  
Bruce Char  
Cheekai Chin  
Mark Clements  
Josh Cohen  
George Corliss  
Meino Cramer  
Nathaniel Daly  
James H. Davenport  
Didier Deshommes  
Jean Della Dora  
Sam Dooley  
Lee Duhem  
Dominique Duval  
Lars Erickson  
Stuart Feldman  
Albrecht Fortenbacher  
Timothy Freeman  
Rudiger Gebauer  
Patricia Gianni  
Teresa Gomez-Diaz  
Johannes Grabmeier  
James Griesmer  
Ming Gu  
Steve Hague  
Mike Hansen  
Bill Hart  
Arthur S. Hathaway  
Karl Hegbloom  
Roy Adler  
George Andrews  
Martin Baker  
Michael Becker  
David R. Barton  
Karen Braman  
Manuel Bronstein  
Luanne Burns  
Quentin Carpent  
Ondrej Certik  
David V. Chudnovsky  
James Cloos  
Christophe Coul  
Robert Corless  
Jeremy Du Croz  
Timothy Daly Sr.  
David Day  
Michael Dewar  
Gabriel Dos Reis  
Lionel Ducos  
Martin Dunstan  
Robert Edwards  
Richard Fateman  
John Fletcher  
George Frances  
Korrinn Fu  
Van de Geijn  
Samantha Goldrich  
Laureiano Gonzalez-Vega  
Matt Grayson  
Vladimir Grinberg  
Jocelyn Guidry  
Satoshi Hamaguchi  
Richard Hanson  
Vilya Harvey  
Dan Hatton  
Ralf Hemmecke
Henderson Antoine Hersen Roger House
Gernot Hueber Pietro Iglio Alejandro Jakubi
Richard Jenks William Kahan Kai Kaminski
Grant Keady Wilfrid Kendall Tony Kennedy
Ted Kosan Paul Kosinski Klaus Kusche
Bernhard Kutzler Tim Lahey Larry Lambe
Kaj Laurson George L. Legendre Franz Lehner
Frederic Lehobey Michel Levaud Howard Levy
Ren-Cang Li Rudiger Loos Michael Lucks
Richard Luczak Cammi Maguire Francois Maltey
Alasdair McAndrew Bob McElrath Michael McGettrick
Edi Meier Ian Meikle David Mentre
Victor S. Miller Gerard Milmeister Mohammed Mobarak
H. Michael Moeller Michael Monagan Marc Moreno-Maza
Scott Morrison Joel Moses Mark Murray
William Naylor Patrice Naudin C. Andrew Neff
John Nelder Godfrey Nolan Arthur Norman
Jinzhong Niu Michael O’Connor Summat Oemrawsingh
Kostas Oikonomou Humberto Ortiz-Zuazaga Julian A. Padget
Bill Page David Parnas Susan Pelzel
Michel Petitot Didier Pinchon Ayal Pinkus
Frederick H. Pitts Jose Alfredo Portes Gregorio Quintana-Orti
Claude Quitte Arthur C. Ralfs Norman Ramsey
Anatoly Raportirenko Albert D. Rich Michael Richardson
Guilherme Reis Huan Ren Renaud Rioiboo
Jean Rivlin Nicolas Robidoux Simon Robinson
Raymond Rogers Michael Rothstein Martin Rubey
Philip Santas Alfred Scherhorn William Schelter
Gerhard Schneider Martin Schoenert Marshall Schor
Frithjof Schulze Fritz Schwarz Steven Segletes
V. Sina Nick Simicich William Sit
Elena Smirnova Jonathan Steinbach Fabio Stumbo
Christine Sundaresan Robert Sutor Moss E. Sweedler
Eugene Surowitz Max Tegmark T. Doug Telford
James Thatcher Balbir Thomas Mike Thomas
Dylan Thurston Steve Toleque Barry Trager
Themos T. Tsikas Gregory Vanuxem Bernhard Wall
Stephen Watt Jaap Weel Juergen Weiss
M. Weller Mark Wegman James Wen
Thorsten Werther Michael Wester R. Clint Whaley
John M. Wiley Berhard Will Clifton J. Williamson
Stephen Wilson Shmuel Winograd Robert Wisbauer
Sandra Wityak Waldemar Wiwianka Knut Wolf
Liu Xiaojun Clifford Yapp David Yun
Vadim Zhytnikov Richard Zippel Evelyn Zoernack
Bruno Zuercher Dan Zwillinger
Contents

1 Details for Programmers 1
  1.1 Makefile ................................. 1
New Foreword

On October 1, 2001 Axiom was withdrawn from the market and ended life as a commercial product. On September 3, 2002 Axiom was released under the Modified BSD license, including this document. On August 27, 2003 Axiom was released as free and open source software available for download from the Free Software Foundation’s website, Savannah.

Work on Axiom has had the generous support of the Center for Algorithms and Interactive Scientific Computation (CAISS) at City College of New York. Special thanks go to Dr. Gilbert Baumslag for his support of the long term goal.

The online version of this documentation is roughly 1000 pages. In order to make printed versions we’ve broken it up into three volumes. The first volume is tutorial in nature. The second volume is for programmers. The third volume is reference material. We’ve also added a fourth volume for developers. All of these changes represent an experiment in print-on-demand delivery of documentation. Time will tell whether the experiment succeeded.

Axiom has been in existence for over thirty years. It is estimated to contain about three hundred man-years of research and has, as of September 3, 2003, 143 people listed in the credits. All of these people have contributed directly or indirectly to making Axiom available. Axiom is being passed to the next generation. I’m looking forward to future milestones.

With that in mind I’ve introduced the theme of the “30 year horizon”. We must invent the tools that support the Computational Mathematician working 30 years from now. How will research be done when every bit of mathematical knowledge is online and instantly available? What happens when we scale Axiom by a factor of 100, giving us 1.1 million domains? How can we integrate theory with code? How will we integrate theorems and proofs of the mathematics with space-time complexity proofs and running code? What visualization tools are needed? How do we support the conceptual structures and semantics of mathematics in effective ways? How do we support results from the sciences? How do we teach the next generation to be effective Computational Mathematicians?

The “30 year horizon” is much nearer than it appears.

Tim Daly
CAISS, City College of New York
November 10, 2003 ((iHy))
Chapter 1

Details for Programmers

1.1 Makefile

This book is actually a literate program[2] and can contain executable source code. In particular, the Makefile for this book is part of the source of the book and is included below. Axiom uses the “noweb” literate programming system by Norman Ramsey[6].

```
PROJECT=bookvol3
TANGLE=/usr/local/bin/NOTANGLE
WEAVE=/usr/local/bin/NOWEAVE
LATEX=/usr/bin/latex
MAKEINDEX=/usr/bin/makeindex

all:
${WEAVE} -t8 -delay ${PROJECT}.pamphlet >${PROJECT}.tex
${LATEX} ${PROJECT}.tex 2>/dev/null 1>/dev/null
${MAKEINDEX} ${PROJECT}.idx
${LATEX} ${PROJECT}.tex 2>/dev/null 1>/dev/null
```

______
Bibliography


http://axiom.axiom-developer.org

http://www.aldor.org


http://www.eecs.harvard.edu/~nr/noweb

[7] Daly, Timothy, ”The Axiom Literate Documentation”
http://axiom.axiom-developer.org/axiom-website/documentation.html