



COMPUTER ALGEBRA ALGORITHMS

Erich Kaltofen

Department of Computer Science, Rensselaer Polytechnic Institute,
Troy, New York 12180-3590

INTRODUCTION

The origins of the discipline of computer algebra can be found in Isaac Newton's *Universal Arithmetic* (1728), where methods for manipulating universal mathematical expressions (i.e. formulas containing symbolic indeterminates) and algorithms for solving equations built with these expressions are systematically discussed. One can interpret the mission of computer algebra as the construction of computer systems that enable scientific or engineering users, for instance, to carry out mathematical manipulation automatically. Indeed, systems with this goal already exist, among them MACSYMA, MAPLE, muMATH, REDUCE, SAC/2, SCRATCHPAD/II, and SMP. These systems carry out scientific computing tasks, whose results are distinguished from numerical computing in two principal aspects. (a) The results are symbolic rather than numerical, as the typical example of the inversion of a symbolic matrix demonstrates.

$$\text{FACTOR} \left(\begin{bmatrix} 1 & x_1 & x_1^2 & x_1^3 \\ 1 & x_2 & x_2^2 & x_2^3 \\ 1 & x_3 & x_3^2 & x_3^3 \\ 1 & x_4 & x_4^2 & x_4^3 \end{bmatrix} \right) \rightarrow$$

1.

$$\left[\begin{array}{cccc} \frac{x_2 x_3 x_4}{(x_2 - x_1)(x_3 - x_1)(x_4 - x_1)} & \frac{-x_2 x_3 x_4}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} & \frac{x_2 x_3 x_4}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} & \frac{-x_2 x_3 x_4}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} \\ \frac{-x_2 x_4 - x_3 x_4 - x_2 x_3}{(x_2 - x_1)(x_3 - x_1)(x_4 - x_1)} & \frac{x_2 x_4 + x_3 x_4 + x_2 x_3}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} & \frac{-x_2 x_4 - x_3 x_4 - x_2 x_3}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} & \frac{x_2 x_3 + x_3 x_3 + x_2 x_2}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} \\ \frac{x_2 + x_3 + x_4}{(x_2 - x_1)(x_3 - x_1)(x_4 - x_1)} & \frac{-x_2 - x_3 - x_4}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} & \frac{x_2 + x_3 + x_4}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} & \frac{-x_2 - x_3 - x_4}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} \\ \frac{-1}{(x_2 - x_1)(x_3 - x_1)(x_4 - x_1)} & \frac{1}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} & \frac{-1}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} & \frac{1}{(x_2 - x_1)(x_3 - x_2)(x_4 - x_2)} \end{array} \right]$$

Algorithms Of Algebra

Tom Høholdt



Algorithms Of Algebra:

Algorithms in Algebraic Geometry and Applications Laureano Gonzalez-Vega, Recio Tomas, 2012-12-06 The present volume contains a selection of refereed papers from the MEGA 94 symposium held in Santander Spain in April 1994 They cover recent developments in the theory and practice of computation in algebraic geometry and present new applications in science and engineering particularly computer vision and theory of robotics The volume will be of interest to researchers working in the areas of computer algebra and symbolic computation as well as to mathematicians and computer scientists interested in gaining access to these topics

Computing in Algebraic Geometry Wolfram Decker, Christoph Lossen, 2006-03-02 This book provides a quick access to computational tools for algebraic geometry the mathematical discipline which handles solution sets of polynomial equations Originating from a number of intense one week schools taught by the authors the text is designed so as to provide a step by step introduction which enables the reader to get started with his own computational experiments right away The authors present the basic concepts and ideas in a compact way

Algorithms for Computer Algebra Keith O. Geddes, Stephen R. Czapor, George Labahn, 1992-09-30 Algorithms for Computer Algebra is the first comprehensive textbook to be published on the topic of computational symbolic mathematics The book first develops the foundational material from modern algebra that is required for subsequent topics It then presents a thorough development of modern computational algorithms for such problems as multivariate polynomial arithmetic and greatest common divisor calculations factorization of multivariate polynomials symbolic solution of linear and polynomial systems of equations and analytic integration of elementary functions Numerous examples are integrated into the text as an aid to understanding the mathematical development The algorithms developed for each topic are presented in a Pascal like computer language An extensive set of exercises is presented at the end of each chapter Algorithms for Computer Algebra is suitable for use as a textbook for a course on algebraic algorithms at the third year fourth year or graduate level Although the mathematical development uses concepts from modern algebra the book is self contained in the sense that a one term undergraduate course introducing students to rings and fields is the only prerequisite assumed The book also serves well as a supplementary textbook for a traditional modern algebra course by presenting concrete applications to motivate the understanding of the theory of rings and fields

Algorithmic Methods in Non-Commutative Algebra J.L. Bueso, José Gómez-Torrecillas, A. Verschoren, 2013-03-09 The already broad range of applications of ring theory has been enhanced in the eighties by the increasing interest in algebraic structures of considerable complexity the so called class of quantum groups One of the fundamental properties of quantum groups is that they are modelled by associative coordinate rings possessing a canonical basis which allows for the use of algorithmic structures based on Groebner bases to study them This book develops these methods in a self contained way concentrating on an in depth study of the notion of a vast class of non commutative rings encompassing most quantum groups the so called Poincaré Birkhoff Witt rings We include algorithms which treat

essential aspects like ideals and bi modules the calculation of homological dimension and of the Gelfand Kirillov dimension the Hilbert Samuel polynomial primality tests for prime ideals etc **Computer Algebra and Symbolic Computation** Joel S. Cohen, 2002-07-19 This book provides a systematic approach for the algorithmic formulation and implementation of mathematical operations in computer algebra programming languages The viewpoint is that mathematical expressions represented by expression trees are the data objects of computer algebra programs and by using a few primitive operations that analyze and **Algorithmic Algebra** Bhubaneswar Mishra, 2012-12-06 Algorithmic Algebra studies some of the main algorithmic tools of computer algebra covering such topics as Gr bner bases characteristic sets resultants and semialgebraic sets The main purpose of the book is to acquaint advanced undergraduate and graduate students in computer science engineering and mathematics with the algorithmic ideas in computer algebra so that they could do research in computational algebra or understand the algorithms underlying many popular symbolic computational systems Mathematica Maple or Axiom for instance Also researchers in robotics solid modeling computational geometry and automated theorem proving community may find it useful as symbolic algebraic techniques have begun to play an important role in these areas The book while being self contained is written at an advanced level and deals with the subject at an appropriate depth The book is accessible to computer science students with no previous algebraic training Some mathematical readers on the other hand may find it interesting to see how algorithmic constructions have been used to provide fresh proofs for some classical theorems The book also contains a large number of exercises with solutions to selected exercises thus making it ideal as a textbook or for self study **Some Tapas of Computer Algebra** Arjeh M. Cohen, Hans Cuypers, Hans Sterk, 1998-12-15 This book presents the basic concepts and algorithms of computer algebra using practical examples that illustrate their actual use in symbolic computation A wide range of topics are presented including Groebner bases real algebraic geometry lie algebras factorization of polynomials integer programming permutation groups differential equations coding theory automatic theorem proving and polyhedral geometry This book is a must read for anyone working in the area of computer algebra symbolic computation and computer science **Ideals, Varieties, and Algorithms** David Cox, John Little, DONAL OSHEA, 2013-03-09 Algebraic Geometry is the study of systems of polynomial equations in one or more variables asking such questions as Does the system have finitely many solutions and if so how can one find them And if there are infinitely many solutions how can they be described and manipulated The solutions of a system of polynomial equations form a geometric object called a variety the corresponding algebraic object is an ideal There is a close relationship between ideals and varieties which reveals the intimate link between algebra and geometry Written at a level appropriate to undergraduates this book covers such topics as the Hilbert Basis Theorem the Nullstellensatz invariant theory projective geometry and dimension theory The algorithms to answer questions such as those posed above are an important part of algebraic geometry This book bases its discussion of algorithms on a generalization of the division algorithm for polynomials in one variable that was only

discovered in the 1960 s Although the algorithmic roots of algebraic geometry are old the computational aspects were neglected earlier in this century This has changed in recent years and new algorithms coupled with the power of fast computers have let to some interesting applications for example in robotics and in geometric theorem proving In preparing a new edition of *Ideals Varieties and Algorithms* the authors present an improved proof of the Buchberger Criterion as well as a proof of Bezout s Theorem Appendix C contains a new section on Axiom and an update about Maple Mathematica and REDUCE

Algorithms in Real Algebraic Geometry Saugata Basu,Richard Pollack,Marie-Françoise Roy,2006-07-06 This is the first graduate textbook on the algorithmic aspects of real algebraic geometry The main ideas and techniques presented form a coherent and rich body of knowledge Mathematicians will find relevant information about the algorithmic aspects Researchers in computer science and engineering will find the required mathematical background Being self contained the book is accessible to graduate students and even for invaluable parts of it to undergraduate students This second edition contains several recent results on discriminants of symmetric matrices and other relevant topics

Algorithmic Algebra and Number Theory B.Heinrich Matzat,Gert-Martin Greuel,Gerhard Hiss,2012-12-06 This book contains 22 lectures presented at the final conference of the Ger man research program Schwerpunktprogramm Algorithmic Number The ory and Algebra 1991 1997 sponsored by the Deutsche Forschungsgemein schaft The purpose of this research program and of the meeting was to bring together developers of computer algebra software and researchers using com putational methods to gain insight into experimental problems and theoret ical questions in algebra and number theory The book gives an overview on algorithmic methods and on results ob tained during this period This includes survey articles on the main research projects within the program algorithmic number theory emphasizing class field theory constructive Galois theory computational aspects of modular forms and of Drinfeld modules computational algebraic geometry including real quantifier elimination and real algebraic geometry and invariant theory of finite groups computational aspects of presentations and representations of groups especially finite groups of Lie type and their Hecke algebras and of the isomorphism problem in group theory Some of the articles illustrate the current state of computer algebra sys tems and program packages developed with support by the research pro gram such as KANT and LiDIA for algebraic number theory SINGULAR RED LOG and INVARI for commutative algebra and invariant theory respec tively and GAP SYSPHOS and CHEVIE for group theory and representation theory

Ideals, Varieties, and Algorithms David A. Cox,John Little,Donal O'Shea,2025-08-23 This text covers topics in algebraic geometry and commutative algebra with careful attention to their practical and computational aspects The first four chapters form the core of the book A comprehensive chart in the Preface illustrates a variety of ways to proceed with the material once these chapters are covered In addition to the fundamentals of algebraic geometry the elimination theorem the extension theorem the closure theorem and the Nullstellensatz there are chapters on polynomial and rational functions between varieties robotics and geometric theorem proving invariant theory of finite groups projective

algebraic geometry dimension theory and progress made over the last decades in computing Gröbner bases The fifth edition builds on the fourth edition in two main ways First a number of typographical errors found by readers and by the authors since 2018 have been corrected Second new material on toric varieties monomial curves and other topics of current interest in algebraic geometry has been added This enhances the opportunities for active learning through new examples new exercises and new projects in Appendix D all supplemented by additional references The book also includes updated computer algebra material in Appendix C The book may be used for a first or second course in undergraduate abstract algebra and with some augmentation perhaps for beginning graduate courses in algebraic geometry or computational commutative algebra Prerequisites for the reader include linear algebra and a proof oriented course It is assumed that the reader has access to a computer algebra system Appendix C describes features of Maple Mathematica and SageMath as well as other systems that are most relevant to the text Pseudocode is used in the text Appendix B carefully describes the pseudocode used From the reviews of previous editions The book gives an introduction to Buchberger's algorithm with applications to syzygies Hilbert polynomials primary decompositions There is an introduction to classical algebraic geometry with applications to the ideal membership problem solving polynomial equations and elimination theory The book is well written The reviewer is sure that it will be an excellent guide to introduce further undergraduates in the algorithmic aspect of commutative algebra and algebraic geometry Peter Schenzel zbMATH 2007 I consider the book to be wonderful The exposition is very clear there are many helpful pictures and there are a great many instructive exercises some quite challenging offers the heart and soul of modern commutative and algebraic geometry The American Mathematical Monthly

Fundamental Problems of Algorithmic Algebra Chee-Keng Yap, 2000 Popular computer algebra systems such as Maple Macysma Mathematica and REDUCE are now basic tools on most computers Efficient algorithms for various algebraic operations underlie all these systems Computer algebra or algorithmic algebra studies these algorithms and their properties and represents a rich intersection of theoretical computer science with classical mathematics Fundamental Problems of Algorithmic Algebra provides a systematic and focused treatment of a collection of core problems the computational equivalents of the classical Fundamental Problem of Algebra and its derivatives Topics covered include the GCD subresultants modular techniques the fundamental theorem of algebra roots of polynomials Sturm theory Gaussian lattice reduction lattices and polynomial factorization linear systems elimination theory Gröbner bases and more Features Presents algorithmic ideas in pseudo code based on mathematical concepts and can be used with any computer mathematics system Emphasizes the algorithmic aspects of problems without sacrificing mathematical rigor Aims to be self contained in its mathematical development Ideal for a first course in algorithmic or computer algebra for advanced undergraduates or beginning graduate students Polynomial Algorithms in Computer Algebra Franz Winkler, 2012-12-06 For several years now I have been teaching courses in computer algebra at the Universität Linz the University of Delaware and the

Universidad de Alcala de Henares In the summers of 1990 and 1992 I have organized and taught summer schools in computer algebra at the Universitat Linz Gradually a set of course notes has emerged from these activities People have asked me for copies of the course notes and different versions of them have been circulating for a few years Finally I decided that I should really take the time to write the material up in a coherent way and make a book out of it Here now is the result of this work Over the years many students have been helpful in improving the quality of the notes and also several colleagues at Linz and elsewhere have contributed to it I want to thank them all for their effort in particular I want to thank B Buchberger who taught me the theory of Grabner bases nearly two decades ago B F Caviness and B D Saunders who first stimulated my interest in various problems in computer algebra G E Collins who showed me how to compute in algebraic domains and J R Sendra with whom I started to apply computer algebra methods to problems in algebraic geometry Several colleagues have suggested improvements in earlier versions of this book However I want to make it clear that I am responsible for all remaining mistakes

Basic Matrix Algebra with Algorithms and Applications Robert A. Liebler, 2018-10-03 Clear prose tight organization and a wealth of examples and computational techniques make Basic Matrix Algebra with Algorithms and Applications an outstanding introduction to linear algebra The author designed this treatment specifically for freshman majors in mathematical subjects and upper level students in natural resources the social sciences business or any discipline that eventually requires an understanding of linear models With extreme pedagogical clarity that avoids abstraction wherever possible the author emphasizes minimal polynomials and their computation using a Krylov algorithm The presentation is highly visual and relies heavily on work with a graphing calculator to allow readers to focus on concepts and techniques rather than on tedious arithmetic Supporting materials including test preparation Maple worksheets are available for download from the Internet This unassuming but insightful and remarkably original treatment is organized into bite sized clearly stated objectives It goes well beyond the LACSG recommendations for a first course while still implementing their philosophy and core material Classroom tested with great success it prepares readers well for the more advanced studies their fields ultimately will require

Graph Algorithms in the Language of Linear Algebra Jeremy Kepner, John Gilbert, 2011-08-04 An introduction to graph algorithms accessible to those without a computer science background

Algorithms in Algebraic Geometry Alicia Dickenstein, Frank-Olaf Schreyer, Andrew J. Sommese, 2010-07-10 In the last decade there has been a burgeoning of activity in the design and implementation of algorithms for algebraic geometric computation The workshop on Algorithms in Algebraic Geometry that was held in the framework of the IMA Annual Program Year in Applications of Algebraic Geometry by the Institute for Mathematics and Its Applications on September 2006 is one tangible indication of the interest This volume of articles captures some of the spirit of the IMA workshop

Computations in Algebraic Geometry with Macaulay 2 David Eisenbud, Daniel R. Grayson, Mike Stillman, Bernd Sturmfels, 2013-03-14 Systems of polynomial equations arise throughout mathematics science and engineering Algebraic geometry provides

powerful theoretical techniques for studying the qualitative and quantitative features of their solution sets Recently developed algorithms have made theoretical aspects of the subject accessible to a broad range of mathematicians and scientists The algorithmic approach to the subject has two principal aims developing new tools for research within mathematics and providing new tools for modeling and solving problems that arise in the sciences and engineering A healthy synergy emerges as new theorems yield new algorithms and emerging applications lead to new theoretical questions This book presents algorithmic tools for algebraic geometry and experimental applications of them It also introduces a software system in which the tools have been implemented and with which the experiments can be carried out Macaulay 2 is a computer algebra system devoted to supporting research in algebraic geometry commutative algebra and their applications The reader of this book will encounter Macaulay 2 in the context of concrete applications and practical computations in algebraic geometry The expositions of the algorithmic tools presented here are designed to serve as a useful guide for those wishing to bring such tools to bear on their own problems A wide range of mathematical scientists should find these expositions valuable This includes both the users of other programs similar to Macaulay 2 for example Singular and CoCoA and those who are not interested in explicit machine computations at all

Applied Algebra, Algebraic Algorithms and Error-Correcting Codes Tom Høholdt, 2003-04-28 This book constitutes the refereed proceedings of the 15th International Symposium on Applied Algebra Algebraic Algorithms and Error Correcting Codes AAECC 15 held in Toulouse France in May 2003 The 25 revised full papers presented together with 2 invited papers were carefully reviewed and selected from 40 submissions Among the subjects addressed are block codes algebra and codes rings fields and AG codes cryptography sequences decoding algorithms and algebra constructions in algebra Galois groups differential algebra and polynomials

Solving Polynomial Equations Alicia Dickenstein, 2005-04-27 This book provides a general introduction to modern mathematical aspects in computing with multivariate polynomials and in solving algebraic systems It presents the state of the art in several symbolic numeric and symbolic numeric techniques including effective and algorithmic methods in algebraic geometry and computational algebra complexity issues and applications ranging from statistics and geometric modelling to robotics and vision Graduate students as well as researchers in related areas will find an excellent introduction to currently interesting topics These cover Groebner and border bases multivariate resultants residues primary decomposition multivariate polynomial factorization homotopy continuation complexity issues and their applications

Ideals, Varieties, and Algorithms David Cox, John Little, Donal O'Shea, 2012-12-22 Written at a level appropriate to undergraduates this book covers such topics as the Hilbert Basis Theorem the Nullstellensatz invariant theory projective geometry and dimension theory The book bases its discussion of algorithms on a generalisation of the division algorithm for polynomials in one variable that was only discovered in the 1960 s Although the algorithmic roots of algebraic geometry are old the computational aspects were neglected earlier in this century This has changed in recent years and new algorithms coupled

with the power of fast computers have led to some interesting applications for example in robotics and in geometric theorem proving. In preparing this new edition the authors present an improved proof of the Buchberger Criterion as well as a proof of Bezout's Theorem.

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