

GRADUATE STUDIES
IN MATHEMATICS **39**

Classical Groups and Geometric Algebra

Larry C. Grove



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Classical Groups And Geometric Algebra

Leo Dorst, Chris Doran, Joan Lasenby



Classical Groups And Geometric Algebra:

Classical Groups and Geometric Algebra Larry C. Grove, 1900 Classical groups named so by Hermann Weyl are groups of matrices or quotients of matrix groups by small normal subgroups Thus the story begins as Weyl suggested with Her All embracing Majesty the general linear group $GL_n V$ of all invertible linear transformations of a vector space V over a field F All further groups discussed are either subgroups of $GL_n V$ or closely related quotient groups Most of the classical groups consist of invertible linear transformations that respect a bilinear form having some geometric significance e g a quadratic form a symplectic form etc Accordingly the author develops the required geometric notions albeit from an algebraic point of view as the end results should apply to vector spaces over more or less arbitrary fields finite or infinite The classical groups have proved to be important in a wide variety of venues ranging from physics to geometry and far beyond In recent years they have played a prominent role in the classification of the finite simple groups This text provides a single source for the basic facts about the classical groups and also includes the required geometrical background information from the first principles It is intended for graduate students who have completed standard courses in linear algebra and abstract algebra The author L C Grove is a well known expert who has published extensively in the subject area *Classical Groups and Geometric Algebra* Larry C. Grove, 2024-12-30 Classical groups named so by Hermann Weyl are groups of matrices or quotients of matrix groups by small normal subgroups Thus the story begins as Weyl suggested with Her All embracing Majesty the general linear group $GL_n V$ of all invertible linear transformations of a vector space V over a field F All further groups discussed are either subgroups of $GL_n V$ or closely related quotient groups Most of the classical groups consist of invertible linear transformations that respect a bilinear form having some geometric significance e g a quadratic form a symplectic form etc Accordingly the author develops the required geometric notions albeit from an algebraic point of view as the end results should apply to vector spaces over more or less arbitrary fields finite or infinite The classical groups have proved to be important in a wide variety of venues ranging from physics to geometry and far beyond In recent years they have played a prominent role in the classification of the finite simple groups This text provides a single source for the basic facts about the classical groups and also includes the required geometrical background information from the first principles It is intended for graduate students who have completed standard courses in linear algebra and abstract algebra The author L C Grove is a well known expert who has published extensively in the subject area **Lectures on Clifford (Geometric) Algebras and Applications** Rafal Ablamowicz, Garret Sobczyk, 2011-06-28 The subject of Clifford geometric algebras offers a unified algebraic framework for the direct expression of the geometric concepts in algebra geometry and physics This bird s eye view of the discipline is presented by six of the world s leading experts in the field it features an introductory chapter on Clifford algebras followed by extensive explorations of their applications to physics computer science and differential geometry The book is ideal for graduate students in mathematics physics and computer science it is appropriate both for

newcomers who have little prior knowledge of the field and professionals who wish to keep abreast of the latest applications

Conjugacy in Finite Classical Groups Giovanni De Franceschi, Martin W. Liebeck, Eamonn A. O'Brien, 2025-05-05 This book provides a comprehensive coverage of the theory of conjugacy in finite classical groups Given such a classical group G the three fundamental problems considered are the following to list a representative for each conjugacy class of G to describe the centralizer of each representative by giving its group structure and a generating set and to solve the conjugacy problem in G namely given two elements of G establish whether they are conjugate and if so find a conjugating element The book presents comprehensive theoretical solutions to all three problems and uses these solutions to formulate practical algorithms In parallel to the theoretical work implementations of these algorithms have been developed in Magma These form a critical component of various general algorithms in computational group theory for example computing character tables and solving conjugacy problems in arbitrary finite groups Discrete Differential Geometry Alexander I.

Bobenko, Yuri B. Suris, 2023-09-14 An emerging field of discrete differential geometry aims at the development of discrete equivalents of notions and methods of classical differential geometry The latter appears as a limit of a refinement of the discretization Current interest in discrete differential geometry derives not only from its importance in pure mathematics but also from its applications in computer graphics theoretical physics architecture and numerics Rather unexpectedly the very basic structures of discrete differential geometry turn out to be related to the theory of integrable systems One of the main goals of this book is to reveal this integrable structure of discrete differential geometry For a given smooth geometry one can suggest many different discretizations Which one is the best This book answers this question by providing fundamental discretization principles and applying them to numerous concrete problems It turns out that intelligent theoretical discretizations are distinguished also by their good performance in applications The intended audience of this book is threefold It is a textbook on discrete differential geometry and integrable systems suitable for a one semester graduate course On the other hand it is addressed to specialists in geometry and mathematical physics It reflects the recent progress in discrete differential geometry and contains many original results The third group of readers at which this book is targeted is formed by specialists in geometry processing computer graphics architectural design numerical simulations and animation They may find here answers to the question How do we discretize differential geometry arising in their specific field Prerequisites for reading this book include standard undergraduate background calculus and linear algebra No knowledge of differential geometry is expected although some familiarity with curves and surfaces can be helpful **Topics in**

Differential Geometry Peter W. Michor, 2008 This book treats the fundamentals of differential geometry manifolds flows Lie groups and their actions invariant theory differential forms and de Rham cohomology bundles and connections Riemann manifolds isometric actions and symplectic and Poisson geometry It gives the careful reader working knowledge in a wide range of topics of modern coordinate free differential geometry in not too many pages A prerequisite for using this book is a

good knowledge of undergraduate analysis and linear algebra

BOOK JACKET

Representations of Semisimple Lie Algebras in the BGG Category $\mathcal{O}$ James E. Humphreys, 2008 This is the first textbook treatment of work leading to the landmark 1979 Kazhdan Lusztig Conjecture on characters of simple highest weight modules for a semisimple Lie algebra $\mathfrak{g}$ over $\mathbb{C}$ The setting is the module category $\mathcal{O}$ introduced by Bernstein Gelfand Gelfand which includes all highest weight modules for $\mathfrak{g}$ such as Verma modules and finite dimensional simple modules Analogues of this category have become influential in many areas of representation theory Part I can be used as a text for independent study or for a mid level one semester graduate course it includes exercises and examples The main prerequisite is familiarity with the structure theory of $\mathfrak{g}$ Basic techniques in category $\mathcal{O}$ such as BGG Reciprocity and Jantzen's translation functors are developed culminating in an overview of the proof of the Kazhdan Lusztig Conjecture due to Beilinson Bernstein and Brylinski Kashiwara The full proof however is beyond the scope of this book requiring deep geometric methods D modules and perverse sheaves on the flag variety Part II introduces closely related topics important in current research parabolic category $\mathcal{O}$ projective functors tilting modules twisting and completion functors and Koszul duality theorem of Beilinson Ginzburg Soergel

Algebra, Logic And Combinatorics Shaun Bullett, Tom Fearn, Frank Smith, 2016-04-21 This book leads readers from a basic foundation to an advanced level understanding of algebra logic and combinatorics Perfect for graduate or PhD mathematical science students looking for help in understanding the fundamentals of the topic it also explores more specific areas such as invariant theory of finite groups model theory and enumerative combinatorics Algebra Logic and Combinatorics is the third volume of the LTCC Advanced Mathematics Series This series is the first to provide advanced introductions to mathematical science topics to advanced students of mathematics Edited by the three joint heads of the London Taught Course Centre for PhD Students in the Mathematical Sciences LTCC each book supports readers in broadening their mathematical knowledge outside of their immediate research disciplines while also covering specialized key areas

A Course in Algebra Ernest Borisovich Vinberg, 2003 Great book The author's teaching experience shows in every chapter Efim Zelmanov University of California San Diego Vinberg has written an algebra book that is excellent both as a classroom text or for self study It is plain that years of teaching abstract algebra have enabled him to say the right thing at the right time Irving Kaplansky MSRI This is a comprehensive text on modern algebra written for advanced undergraduate and basic graduate algebra classes The book is based on courses taught by the author at the Mechanics and Mathematics Department of Moscow State University and at the Mathematical College of the Independent University of Moscow The unique feature of the book is that it contains almost no technically difficult proofs Following his point of view on mathematics the author tried whenever possible to replace calculations and difficult deductions with conceptual proofs and to associate geometric images to algebraic objects Another important feature is that the book presents most of the topics on several levels allowing the student to move smoothly from

initial acquaintance to thorough study and deeper understanding of the subject Presented are basic topics in algebra such as algebraic structures linear algebra polynomials groups as well as more advanced topics like affine and projective spaces tensor algebra Galois theory Lie groups associative algebras and their representations Some applications of linear algebra and group theory to physics are discussed Written with extreme care and supplied with more than 200 exercises and 70 figures the book is also an excellent text for independent study

Modern Geometric Structures and Fields Сепреј

Петровић Новиков, Искандер Асановић Тайманов, 2006 Presents the basics of Riemannian geometry in its modern form as geometry of differentiable manifolds and the important structures on them This book shows that Riemannian geometry has a great influence to several fundamental areas of modern mathematics and its applications

The Finite Simple Groups

Robert Wilson, 2009-12-14 This book is intended as an introduction to all the finite simple groups During the monumental struggle to classify the finite simple groups and indeed since a huge amount of information about these groups has been accumulated Conveying this information to the next generation of students and researchers not to mention those who might wish to apply this knowledge has become a major challenge With the publication of the two volumes by Aschbacher and Smith 12 13 in 2004 we can reasonably regard the proof of the Classification Theorem for Finite Simple Groups usually abbreviated CFSG as complete Thus it is timely to attempt an overview of all the non abelian finite simple groups in one volume For expository purposes it is convenient to divide them into four basic types namely the alternating classical exceptional and sporadic groups The study of alternating groups soon develops into the theory of permutation groups which is well served by the classic text of Wielandt 170 and more modern treatments such as the comprehensive introduction by Dixon and Mortimer 53 and more specialised texts such as that of Cameron 19

Linear Algebra in Action Harry

Dym, 2007 Linear algebra permeates mathematics perhaps more so than any other single subject It plays an essential role in pure and applied mathematics statistics computer science and many aspects of physics and engineering This book conveys in a user friendly way the basic and advanced techniques of linear algebra from the point of view of a working analyst The techniques are illustrated by a wide sample of applications and examples that are chosen to highlight the tools of the trade In short this is material that the author wishes he had been taught as a graduate student Roughly the first third of the book covers the basic material of a first course in linear algebra The remaining chapters are devoted to applications drawn from vector calculus numerical analysis control theory complex analysis convexity and functional analysis In particular fixed point theorems extremal problems matrix equations zero location and eigenvalue location problems and matrices with nonnegative entries are discussed Appendices on useful facts from analysis and supplementary information from complex function theory are also provided for the convenience of the reader The book is suitable as a text or supplementary reference for a variety of courses on linear algebra and its applications as well as for self study

Representations of Hecke Algebras at Roots of

Unity Meinolf Geck, Nicolas Jacon, 2011-05-18 The modular representation theory of Iwahori Hecke algebras and this theory s

connection to groups of Lie type is an area of rapidly expanding interest it is one that has also seen a number of breakthroughs in recent years In classifying the irreducible representations of Iwahori Hecke algebras at roots of unity this book is a particularly valuable addition to current research in this field Using the framework provided by the Kazhdan Lusztig theory of cells the authors develop an analogue of James 1970 characteristic free approach to the representation theory of Iwahori Hecke algebras in general Presenting a systematic and unified treatment of representations of Hecke algebras at roots of unity this book is unique in its approach and includes new results that have not yet been published in book form It also serves as background reading to further active areas of current research such as the theory of affine Hecke algebras and Cherednik algebras The main results of this book are obtained by an interaction of several branches of mathematics namely the theory of Fock spaces for quantum affine Lie algebras and Ariki's theorem the combinatorics of crystal bases the theory of Kazhdan Lusztig bases and cells and computational methods This book will be of use to researchers and graduate students in representation theory as well as any researchers outside of the field with an interest in Hecke algebras

Geometric Algebra with Applications in Science and Engineering Eduardo Bayro Corrochano, Garret Sobczyk, 2011-06-28 The goal of this book is to present a unified mathematical treatment of diverse problems in mathematics physics computer science and engineering using geometric algebra Geometric algebra was invented by William Kingdon Clifford in 1878 as a unification and generalization of the works of Grassmann and Hamilton which came more than a quarter of a century before Whereas the algebras of Clifford and Grassmann are well known in advanced mathematics and physics they have never made an impact in elementary textbooks where the vector algebra of Gibbs Heaviside still predominates The approach to Clifford algebra adopted in most of the articles here was pioneered in the 1960s by David Hestenes Later together with Garret Sobczyk he developed it into a unified language for mathematics and physics Sobczyk first learned about the power of geometric algebra in classes in electrodynamics and relativity taught by Hestenes at Arizona State University from 1966 to 1967 He still vividly remembers a feeling of disbelief that the fundamental geometric product of vectors could have been left out of his undergraduate mathematics education Geometric algebra provides a rich general mathematical framework for the development of multilinear algebra projective and affine geometry calculus on a manifold the representation of Lie groups and Lie algebras the use of the horosphere and many other areas This book is addressed to a broad audience of applied mathematicians physicists computer scientists and engineers

Geometric Algebra for Computer Science Leo Dorst, Daniel Fontijne, Stephen Mann, 2010-07-26 Until recently almost all of the interactions between objects in virtual 3D worlds have been based on calculations performed using linear algebra Linear algebra relies heavily on coordinates however which can make many geometric programming tasks very specific and complex often a lot of effort is required to bring about even modest performance enhancements Although linear algebra is an efficient way to specify low level computations it is not a suitable high level language for geometric programming Geometric Algebra for

Computer Science presents a compelling alternative to the limitations of linear algebra. Geometric algebra or GA is a compact, time effective and performance enhancing way to represent the geometry of 3D objects in computer programs. In this book you will find an introduction to GA that will give you a strong grasp of its relationship to linear algebra and its significance for your work. You will learn how to use GA to represent objects and perform geometric operations on them. And you will begin mastering proven techniques for making GA an integral part of your applications in a way that simplifies your code without slowing it down. The first book on Geometric Algebra for programmers in computer graphics and entertainment computing. Written by leaders in the field providing essential information on this new technique for 3D graphics. This full colour book includes a website with GAVIEWER a program to experiment with GA.

Applications of Geometric Algebra in Computer Science and Engineering Leo Dorst, Chris Doran, Joan Lasenby, 2012-12-06 Geometric algebra has established itself as a powerful and valuable mathematical tool for solving problems in computer science, engineering, physics and mathematics. The articles in this volume, written by experts in various fields, reflect an interdisciplinary approach to the subject and highlight a range of techniques and applications. Relevant ideas are introduced in a self contained manner and only a knowledge of linear algebra and calculus is assumed.

Features and Topics The mathematical foundations of geometric algebra are explored. Applications in computational geometry include models of reflection and ray tracing and a new and concise characterization of the crystallographic groups. Applications in engineering include robotics, image geometry, control, pose estimation, inverse kinematics and dynamics control and visual navigation. Applications in physics include rigid body dynamics, elasticity and electromagnetism. Chapters dedicated to quantum information theory dealing with multi particle entanglement, MRI and relativistic generalizations.

Practitioners professionals and researchers working in computer science, engineering, physics and mathematics will find a wide range of useful applications in this state of the art survey and reference book. Additionally, advanced graduate students interested in geometric algebra will find the most current applications and methods discussed.

Computer Algebra and Geometric Algebra with Applications Hongbo Li, Peter J. Olver, Gerald Sommer, 2005-06-20 Mathematics. Mechanization consists of theory, software and application of computerized mathematical activities such as computing, reasoning and discovering. Its unique feature can be succinctly described as AAA: Algebraization, Algorithmization, Application. The name Mathematics Mechanization has its origin in the work of Hao Wang. 1960s one of the pioneers in using computers to do research in mathematics, particularly in automated theorem proving. Since the 1970s this research direction has been actively pursued and extensively developed by Prof. Wen-tsun Wu and his followers. It differs from the closely related disciplines like Computer Mathematics, Symbolic Computation and Automated Reasoning in that its goal is to make algorithmic studies and applications of mathematics the major trend of mathematics development in the information age. The International Workshop on Mathematics Mechanization (IWMM) was initiated by Prof. Wu in 1992 and has ever since been held by the Key Laboratory of Mathematics Mechanization (KLMM) of the Chinese Academy of Sciences. There have been

seven workshops of the series up to now At each workshop several experts are invited to deliver plenary lectures on cutting edge methods and algorithms of the selected theme The workshop is also a forum for people working on related subjects to meet collaborate and exchange ideas

Differential Algebraic Topology Matthias Kreck, 2010 This book presents a geometric introduction to the homology of topological spaces and the cohomology of smooth manifolds The author introduces a new class of stratified spaces so called stratifolds He derives basic concepts from differential topology such as Sard's theorem partitions of unity and transversality Based on this homology groups are constructed in the framework of stratifolds and the homology axioms are proved This implies that for nice spaces these homology groups agree with ordinary singular homology Besides the standard computations of homology groups using the axioms straightforward constructions of important homology classes are given The author also defines stratifold cohomology groups following an idea of Quillen Again certain important cohomology classes occur very naturally in this description for example the characteristic classes which are constructed in the book and applied later on One of the most fundamental results Poincaré duality is almost a triviality in this approach Some fundamental invariants such as the Euler characteristic and the signature are derived from cohomology groups These invariants play a significant role in some of the most spectacular results in differential topology In particular the author proves a special case of Hirzebruch's signature theorem and presents as a highlight Milnor's exotic 7 spheres This book is based on courses the author taught in Mainz and Heidelberg Readers should be familiar with the basic notions of point set topology and differential topology The book can be used for a combined introduction to differential and algebraic topology as well as for a quick presentation of cohomology in a course about differential geometry

Geometric Algebra Applications Vol. III Eduardo Bayro-Corrochano, 2024-09-26 The goal of Geometric Algebra Applications Vol III Integral Transforms Machine Learning and Quantum Computing is to present a unified mathematical treatment of diverse problems in the general domain like Clifford Fourier Transforms Deep Learning and Geometric Algebra Convolutional Neural Networks Quaternion Quantum Fourier Transform and Geometric Quantum Computing Topics and features Introduces nonspecialists to Clifford or geometric algebra and by example encourages the reader to learn to compute using geometric entities and geometric formulations A study in depth for applications of Lie group theory Lie algebra projective geometry and the algebra of incidence using the conformal geometric algebra Features the computing frameworks of the linear model n dimensional affine plane and the nonlinear model of Euclidean space known as the horosphere and addresses the relationships of these models to conformal affine and projective geometries Includes a thorough study of Integral transforms Quaternion and Clifford Transforms quaternion analytic signal monogenic signals Hilbert transform Riesz transform Clifford Fourier Transform Quaternion Wavelet transforms Quaternion Quantum Fourier Transform 3D Radon Transform and Hough Transform in geometric algebra Color image processing using the color model HSV Quaternion Split rotors and motors and the space time Lorentz transform Geometric neural computing using Split Quaternions Geometric Algebra neural networks

Clifford Support Vector Machine and Neuro Control Thorough discussion of several tasks of computer vision graphics neurocomputing and robotics machine learning Deep Learning and CNNs and Geometric Quantum Computing using the geometric algebra framework 130 exercises and hints for the development of future computer software packages for extensive calculations in geometric algebra An entire section is dedicated to explaining how one should write the subroutines in C Python Matlab and Maple to carry out efficient geometric computations in the geometric algebra framework Furthermore it is shown how program code can be optimized for real time computations The book is an essential resource for applied mathematicians physicists computer scientists graphics engineering AI and Machine Learning researchers roboticists and mechanical and electrical engineers neurocomputing researchers neuroscientists and quantum computing specialists It clarifies and demonstrates the importance of geometric computing for building autonomous systems and pushes forward advances in geometric cybernetics research *Canadian Mathematical Bulletin* ,1968

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