

## Volume Comparison and Its Applications in Riemann–Finsler Geometry

Zhongmin Shen\*

*Department of Mathematical Science, Indiana University–Purdue University at Indianapolis,  
Indianapolis, Indiana 46202-3216*

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We introduce a new geometric quantity, the *mean covariation* for Finsler metrics, and establish a volume comparison theorem. As an application, we obtain some precompactness and finiteness theorems for Finsler manifolds. © 1997 Academic Press

### 1. INTRODUCTION

Early work in conjunction with the global comparison geometry of Finsler manifolds was done by L. Auslander [A], who proved that if a complete Finsler  $n$ -manifold  $(M, F)$  satisfies  $\text{Ric}_M \geq (n-1)$ , then the diameter  $\text{diam}_M \leq \pi$ . In particular,  $\pi_1(M)$  is finite. This is the Bonnet–Myers theorem if  $F$  is Riemannian. Further, he proved that if a complete Finsler manifold  $(M, F)$  has non-positive flag curvature, then the exponential map  $\exp_x: T_x M \rightarrow M$  is a local  $C^1$ -diffeomorphism. This is the Cartan–Hadamard theorem if  $F$  is Riemannian. We point out that Auslander used the Cartan connection and stated the above theorems under slightly stronger conditions on curvatures, because he did not realize that the curvature terms in the second variation formula can be simplified to the flag curvature. See [AZ2, BCh] for simplified formulas. We remark that the flag curvature is independent of a particular choice of connections, and hence is of particular interest in the metric geometry of Finsler manifolds. See [L, AZ1, D1–D3, GKR, Mo1, Mo2, K1, K2, BCh], etc., for other interesting work on global Finsler geometry.

In Riemann geometry, the Bishop–Gromov volume comparison theorem [BCr, GLP] plays a very important role in the global differential geometry of Riemann manifolds. One of its applications is the Gromov precompactness theorem for the class  $\mathfrak{C}(n, \lambda, d)$  with respect to the Gromov–Hausdorff distance  $d_{GH}$ , where  $\mathfrak{C}(n, \lambda, d)$  denotes the set of all Riemann manifolds  $(M, g)$  satisfying  $\text{Ric}_M \geq (n-1)\lambda$  and  $\text{diam}_M \leq d$ . For  $\varepsilon > 0$ ,  $R \geq 1$ , consider

\* E-mail: zshen@math.iupui.edu.

# Riemannfinsler Geometry

**P.L. Antonelli**



## **Riemannfinsler Geometry:**

*Riemann-finsler Geometry* Shiing-shen Chern, Zhongmin Shen, 2005-05-10 Riemann Finsler geometry is a subject that concerns manifolds with Finsler metrics including Riemannian metrics It has applications in many fields of the natural sciences Curvature is the central concept in Riemann Finsler geometry This invaluable textbook presents detailed discussions on important curvatures such as the Cartan torsion the S curvature the Landsberg curvature and the Riemann curvature It also deals with Finsler metrics with special curvature or geodesic properties such as projectively flat Finsler metrics Berwald metrics Finsler metrics of scalar flag curvature or isotropic S curvature etc Instructive examples are given in abundance for further description of some important geometric concepts The text includes the most recent results although many of the problems discussed are classical

**An Introduction to Riemann-Finsler Geometry** David Dai-Wai Bao, S.-S. Chern, Z. Shen, 2000-03-17 This book focuses on the elementary but essential problems in Riemann Finsler Geometry which include a repertoire of rigidity and comparison theorems and an array of explicit examples illustrating many phenomena which admit only Finslerian interpretations This book offers the most modern treatment of the topic EMS Newsletter

*An Introduction to Riemann-Finsler Geometry* David Dai-Wai Bao, Shiing-Shen Chern, Zhongmin Shen, 2000

**A Sampler of Riemann-Finsler Geometry** David Dai-Wai Bao, 2004-11 These expository accounts treat issues related to volume geodesics curvature and mathematical biology with instructive examples

*An Introduction to Riemann-Finsler Geometry* D. Bao, S.-S. Chern, Z. Shen, 2012-12-06 In Riemannian geometry measurements are made with both yardsticks and protractors These tools are represented by a family of inner products In Riemann Finsler geometry or Finsler geometry for short one is in principle equipped with only a family of Minkowski norms So ardsticks are assigned but protractors are not With such a limited tool kit it is natural to wonder just how much geometry one can uncover and describe It now appears that there is a reasonable answer Finsler geometry encompasses a solid repertoire of rigidity and comparison theorems most of them founded upon a fruitful analogue of the sectional curvature There is also a bewildering array of explicit examples illustrating many phenomena which admit only Finslerian interpretations This book focuses on the elementary but essential items among these results Much thought has gone into making the account a teachable one

**Introduction To Modern Finsler Geometry** Yi-bing Shen, Zhongmin Shen, 2016-02-25 This comprehensive book is an introduction to the basics of Finsler geometry with recent developments in its area It includes local geometry as well as global geometry of Finsler manifolds In Part I the authors discuss differential manifolds Finsler metrics the Chern connection Riemannian and non Riemannian quantities Part II is written for readers who would like to further their studies in Finsler geometry It covers projective transformations comparison theorems fundamental group minimal immersions harmonic maps Einstein metrics conformal transformations amongst other related topics The authors made great efforts to ensure that the contents are accessible to senior undergraduate students graduate students mathematicians and scientists

*Lectures on Finsler*

*Geometry* Zhongmin Shen, 2001 In 1854 B Riemann introduced the notion of curvature for spaces with a family of inner products There was no significant progress in the general case until 1918 when P Finsler studied the variation problem in regular metric spaces Around 1926 L Berwald extended Riemann's notion of curvature to regular metric spaces and introduced an important non Riemannian curvature using his connection for regular metrics Since then Finsler geometry has developed steadily In his Paris address in 1900 D Hilbert formulated 23 problems the 4th and 23rd problems being in Finsler's category Finsler geometry has broader applications in many areas of science and will continue to develop through the efforts of many geometers around the world Usually the methods employed in Finsler geometry involve very complicated tensor computations Sometimes this discourages beginners Viewing Finsler spaces as regular metric spaces the author discusses the problems from the modern metric geometry point of view The book begins with the basics on Finsler spaces including the notions of geodesics and curvatures then deals with basic comparison theorems on metrics and measures and their applications to the Levy concentration theory of regular metric measure spaces and Gromov's Hausdorff convergence theory

**Gromov, Cauchy and Causal Boundaries for Riemannian, Finslerian and Lorentzian Manifolds** Jose Luis Flores, J. Herrera, M. Sánchez, 2013-10-23 Recently the old notion of causal boundary for a spacetime  $V$  has been redefined consistently The computation of this boundary  $V$  on any standard conformally stationary spacetime  $V \times \mathbb{R} \times M$  suggests a natural compactification  $MB$  associated to any Riemannian metric on  $M$  or more generally to any Finslerian one The corresponding boundary  $BM$  is constructed in terms of Busemann type functions Roughly  $BM$  represents the set of all the directions in  $M$  including both asymptotic and finite or incomplete directions This Busemann boundary  $BM$  is related to two classical boundaries the Cauchy boundary  $CM$  and the Gromov boundary  $GM$  The authors' aims are 1 to study the subtleties of both the Cauchy boundary for any generalized possibly non symmetric distance and the Gromov compactification for any possibly incomplete Finsler manifold 2 to introduce the new Busemann compactification  $MB$  relating it with the previous two completions and 3 to give a full description of the causal boundary  $V$  of any standard conformally stationary spacetime J L Flores and J Herrera University of Malaga Spain and M Sánchez University of Granada Spain Publisher's note [Finsler Geometry](#) Xinyue Cheng, Zhongmin Shen, 2013-01-29 Finsler Geometry An Approach via Randers Spaces exclusively deals with a special class of Finsler metrics Randers metrics which are defined as the sum of a Riemannian metric and a 1-form Randers metrics derive from the research on General Relativity Theory and have been applied in many areas of the natural sciences They can also be naturally deduced as the solution of the Zermelo navigation problem The book provides readers not only with essential findings on Randers metrics but also the core ideas and methods which are useful in Finsler geometry It will be of significant interest to researchers and practitioners working in Finsler geometry even in differential geometry or related natural fields Xinyue Cheng is a Professor at the School of Mathematics and Statistics of Chongqing University of Technology China Zhongmin Shen is a Professor at the Department of Mathematical Sciences of Indiana University Purdue

University USA      **Finsler Geometry and Applications** Aurel Bejancu,1990      **Finslerian Geometries** P.L.

Antonelli,2012-12-06 The International Conference on Finsler and Lagrange Geometry and its Applications A Meeting of Minds took place August 13 20 1998 at the University of Alberta in Edmonton Canada The main objective of this meeting was to help acquaint North American geometers with the extensive modern literature on Finsler geometry and Lagrange geometry of the Japanese and European schools each with its own venerable history on the one hand and to communicate recent advances in stochastic theory and Hodge theory for Finsler manifolds by the younger North American school on the other The intent was to bring together practitioners of these schools of thought in a Canadian venue where there would be ample opportunity to exchange information and have cordial personal interactions The present set of refereed papers begins with the Pedagogical Section I where introductory and brief survey articles are presented one from the Japanese School and two from the European School Romania and Hungary These have been prepared for non experts with the intent of explaining basic points of view The Section III is the main body of work It is arranged in alphabetical order by author Section II gives a brief account of each of these contributions with a short reference list at the end More extensive references are given in the individual articles      *The Geometry of Finsler Spaces: an Approach Via Special Finsler Metric* Sruthy Baby,2019-10-20

Finsler geometry is Riemannian geometry without the restriction that the line element be quadratic It has applications in many field of natural science especially in mechanics gravitational theory electromagnetism information geometry etc This book presents some work done by the author on the theory of projective change between two Finsler spaces Conformal change of Douglas space with special Finsler metric Nonholonomic Frames for Finsler space with special metric Reversible geodesics of Finslerian space Complex Finsler space Rander conformal change of Finsler spaces and the curvature properties of Finsler space The chapters included in this book contains fundamental topic of modern Riemann Finsler geometry including the notion of curvature projectively flat metrics dually flat metrics which are interesting not only for specialists in Finsler Geometry but for researchers in Riemann Geometry or other field of differential geometry The book provides readers with essential findings on a special type of Finsler metric which can be considered as a generalization of Randers metric and square metric The text includes the most recent topics in Finsler Geometry like Reversible geodesics of Finsler space R Complex Finsler space and transformation on Finsler metric This book shall be of benefit to students in the field of Differential geometry and will be of interest to physicists and mathematical biologists      Visualization and Processing of Tensors and Higher Order Descriptors for Multi-Valued Data Carl-Fredrik Westin,Anna Vilanova,Bernhard

Burgeth,2014-07-17 Arising from the fourth Dagstuhl conference entitled Visualization and Processing of Tensors and Higher Order Descriptors for Multi Valued Data 2011 this book offers a broad and vivid view of current work in this emerging field Topics covered range from applications of the analysis of tensor fields to research on their mathematical and analytical properties Part I Tensor Data Visualization surveys techniques for visualization of tensors and tensor fields in engineering

discusses the current state of the art and challenges and examines tensor invariants and glyph design including an overview of common glyphs The second Part Representation and Processing of Higher order Descriptors describes a matrix representation of local phase outlines mathematical morphological operations techniques extended for use in vector images and generalizes erosion to the space of diffusion weighted MRI Part III Higher Order Tensors and Riemannian Finsler Geometry offers powerful mathematical language to model and analyze large and complex diffusion data such as High Angular Resolution Diffusion Imaging HARDI and Diffusion Kurtosis Imaging DKI A Part entitled Tensor Signal Processing presents new methods for processing tensor valued data including a novel perspective on performing voxel wise morphometry of diffusion tensor data using kernel based approach explores the free water diffusion model and reviews proposed approaches for computing fabric tensors emphasizing trabecular bone research The last Part Applications of Tensor Processing discusses metric and curvature tensors two of the most studied tensors in geometry processing Also covered is a technique for diagnostic prediction of first episode schizophrenia patients based on brain diffusion MRI data The last chapter presents an interactive system integrating the visual analysis of diffusion MRI tractography with data from electroencephalography

**Study on Some Transformations of Riemann-Finsler Spaces** Manoj Kumar, 2016 Finsler geometry generalizes Riemannian geometry in the same sense that Banach spaces generalize Hilbert spaces This book presents some transformations in Riemann Finsler geometry which have recently undergone significant development but have not had a pedagogical treatment elsewhere Each article will open the door to an active area of research and is suitable for a special topics course in graduate level differential geometry

**Finsler Geometry, Sapporo 2005** Makoto Matsumoto, 2007 The volume contains surveys and original articles based on the talks given at the 40 th Finsler Symposium on Finsler Geometry held in the period September 9 10 2005 at Hokkaido Tokai University Sapporo Japan The Symposium's purpose was not only a meeting of the Finsler geometers from Japan and abroad but also to commemorate the memory of the late Professor Makoto Matsumoto The papers included in this volume contain fundamental topics of modern Riemann Finsler geometry interesting not only for specialists in Finsler geometry but for researchers in Riemannian geometry or other fields of differential geometry and its applications also Published by Mathematical Society of Japan and distributed by World Scientific Publishing Co for all markets except North America

**Finsler and Lagrange Geometries** Mihai Anastasiei, P.L. Antonelli, 2013-06-29 In the last decade several international conferences on Finsler Lagrange and Hamilton geometries were organized in Bra ov Romania 1994 Seattle USA 1995 Edmonton Canada 1998 besides the Seminars that periodically are held in Japan and Romania All these meetings produced important progress in the field and brought forth the appearance of some reference volumes Along this line a new International Conference on Finsler and Lagrange Geometry took place August 26 31 2001 at the Al I Cuza University in Ia i Romania This Conference was organized in the framework of a Memorandum of Understanding 1994 2004 between the Al I Cuza University in Ia i Romania and the University of Alberta in Edmonton Canada It

was especially dedicated to Prof Dr Peter Louis Antonelli the liaison officer in the Memorandum an untired promoter of Finsler Lagrange and Hamilton geometries very close to the Romanian School of Geometry led by Prof Dr Radu Miron The dedication wished to mark also the 60th birthday of Prof Dr Peter Louis Antonelli With this occasion a Diploma was given to Professor Dr Peter Louis Antonelli conferring the title of Honorary Professor granted to him by the Senate of the oldest Romanian University 140 years the Al I Cuza University Ia i Romania There were almost fifty participants from Egypt Greece Hungary Japan Romania USA There were scheduled 45 minutes lectures as well as short communications

*The Theory of Finslerian Laplacians and Applications* P.L. Antonelli, Bradley C. Lackey, 2012-12-06 Finslerian Laplacians have arisen from the demands of modelling the modern world However the roots of the Laplacian concept can be traced back to the sixteenth century Its phylogeny and history are presented in the Prologue of this volume The text proper begins with a brief introduction to stochastically derived Finslerian Laplacians facilitated by applications in ecology epidemiology and evolutionary biology The mathematical ideas are then fully presented in section II with generalizations to Lagrange geometry following in section III With section IV the focus abruptly shifts to the local mean value approach to Finslerian Laplacians and a Hodge de Rham theory is developed for the representation on real cohomology classes by harmonic forms on the base manifold Similar results are proved in sections II and IV each from different perspectives Modern topics treated include nonlinear Laplacians Bochner and Lichnerowicz vanishing theorems Weitzenböck formulas and Finslerian spinors and Dirac operators The tools developed in this book will find uses in several areas of physics and engineering but especially in the mechanics of inhomogeneous media e.g. Cosserat continua Audience This text will be of use to workers in stochastic processes differential geometry nonlinear analysis epidemiology ecology and evolution as well as physics of the solid state and continua

Cpt And Lorentz Symmetry - Proceedings Of The Sixth Meeting V Alan Kostelecky, 2014-01-15 This book contains the Proceedings of the Sixth Meeting on CPT and Lorentz Symmetry held at Indiana University in Bloomington on June 17-21 2013 The Meeting focused on tests of these fundamental symmetries and on related theoretical issues including scenarios for possible violations Topics covered at the meeting include searches for CPT and Lorentz violations involving accelerator and collider experiments atomic nuclear and particle decays birefringence dispersion and anisotropy in cosmological sources clock comparison measurements electromagnetic resonant cavities and lasers tests of the equivalence principle gauge and Higgs particles high energy astrophysical observations laboratory tests of gravity matter interferometry neutrino oscillations and propagation oscillations and decays of neutral mesons particle antiparticle comparisons post newtonian gravity in the solar system and beyond second and third generation particles space based missions spectroscopy of hydrogen and antihydrogen spin polarized matter and time of flight measurements Theoretical discussions include physical effects at the level of the Standard Model General Relativity and beyond the possible origins and mechanisms for Lorentz and CPT violations classical and quantum issues in field theory particle physics gravity and string theory and mathematical

foundations including Finsler geometry      *Homogeneous Finsler Spaces* Shaoqiang Deng, 2012-08-01 Homogeneous Finsler Spaces is the first book to emphasize the relationship between Lie groups and Finsler geometry and the first to show the validity in using Lie theory for the study of Finsler geometry problems This book contains a series of new results obtained by the author and collaborators during the last decade The topic of Finsler geometry has developed rapidly in recent years One of the main reasons for its surge in development is its use in many scientific fields such as general relativity mathematical biology and phycology study of algae This monograph introduces the most recent developments in the study of Lie groups and homogeneous Finsler spaces leading the reader to directions for further development The book contains many interesting results such as a Finslerian version of the Myers Steenrod Theorem the existence theorem for invariant non Riemannian Finsler metrics on coset spaces the Berwaldian characterization of globally symmetric Finsler spaces the construction of examples of reversible non Berwaldian Finsler spaces with vanishing S curvature and a classification of homogeneous Randers spaces with isotropic S curvature and positive flag curvature Readers with some background in Lie theory or differential geometry can quickly begin studying problems concerning Lie groups and Finsler geometry

**Frontiers In Mathematical Analysis And Numerical Methods: In Memory Of Jacques-louis Lions** Tatsien Li, 2004-07-26 This invaluable volume is a collection of articles in memory of Jacques Louis Lions a leading mathematician and the founder of the Contemporary French Applied Mathematics School The contributions have been written by his friends colleagues and students including C Bardos A Bensoussan S S Chern P G Ciarlet R Glowinski Gu Chaohao B Malgrange G Marchuk O Pironneau W Strauss R Temam etc The book concerns many important results in analysis geometry numerical methods fluid mechanics control theory etc



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