

SOBOLEV SPACES AND (P, Q) -QUASICONFORMAL MAPPINGS OF CARNOT GROUPS¹⁾²⁾

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In 1968 at the first Donetsk colloquium on mapping theory Yu. G. Reshetnyak stated the problem of describing all isomorphisms φ^* between the homogeneous Sobolev spaces L_n^1 which are generated by quasiconformal mappings φ of the Euclidean space \mathbb{R}^n by the rule $\varphi^*(u) = u \circ \varphi$. It was shown in [1] that these isomorphisms are exactly the latticial isomorphisms of the spaces L_n^1 . The approach in [1] to Reshetnyak's problem is natural to consider in the context of the preceding results (see, for instance, [2, pp. 419–420]). The theorems by Banach, Stone, Eilenberg, Arens and Kelley, Hewitt, and Gelfand and Kolmogorov provide conditions on various structures of the space $C(S)$ of continuous functions whose isomorphisms determine the topological space S up to homeomorphism. We recall Stone's result according to which $C(S)$, regarded as a lattice ordered group, determines S . On the other hand, M. Nakai [3] and L. Lewis [4] established that the isomorphism between two Royden algebras is equivalent to the quasiconformal equivalence of the domains of definition. Distinguishing in the homogeneous Sobolev space L_n^1 two structures, the structure of a vector lattice and the structure of a seminormed space, we now obtain a situation close to Stone's article in an algebraic sense and to Nakai's article in a metric sense. This view of the problem is most natural as allowing us to reconstruct a mapping despite keeping at a minimum "information" for finding the mapping, as well as to prove its continuity, and to discover its metric properties.

The following problem arises in the framework of the approach of [1] to Reshetnyak's problem: what are the metric and analytical properties of a measurable mapping φ inducing the isomorphism φ^* by the rule $\varphi^*(f) = f \circ \varphi$, $f \in L_n^1$. Taking various function spaces L_n^1 , we arrive at different problems: the Sobolev spaces W_p^1 , $p > n$, were considered in [5]; the homogeneous Besov spaces $B_p^l(\mathbb{R}^n)$, $n > 1$, $lp = n$, for $p = n + 1$ in [6] and for $p > n + 1$ in [7]; the Sobolev spaces W_p^1 , $n - 1 < p < n$, in [8]; the Sobolev spaces W_p^1 , $1 \leq p < n$, (and the spaces of potentials) in [9, 10]; and the three-index scales of Nikol'skii-Besov spaces and Lizorkin-Triebel spaces (and their anisotropic analogs) in [11]. In [12], the theory of multipliers was applied to the change-of-variable problem in Sobolev spaces. The results of [5–11] factually assert that, depending on the relation between the order of smoothness, the summability exponent, and the dimension, the fact that the operator φ^* in an isomorphism implies quasiconformality or quasi-isometry of the mapping in a metric on the domain which is adequate to the geometry of the function space in question.

Qualitatively new effects appear in this problem when we study the analytical and metric properties of homeomorphisms inducing bounded operators between Sobolev spaces. We recall the main result of [13, 14]:

Theorem 1. Suppose that $\varphi : \Omega \rightarrow \Omega'$ is a homeomorphism between spatial domains $\Omega, \Omega' \subset \mathbb{R}^n$, $n \geq 2$. Then the following assertions are equivalent:

- (1) the mapping φ induces the bounded operator $\varphi^* : L_p^1(\Omega') \rightarrow L_p^1(\Omega)$, $p \in [1, \infty)$, by the rule $\varphi^*(f) = f \circ \varphi$;
- (2) the mapping φ belongs to L_{loc}^1 and $|\nabla \varphi(x)|^p \leq K_p |\det \nabla \varphi(x)|$ almost everywhere in Ω , $p \in [1, \infty)$.

¹⁾ To the unfaded memory of Sergei L'vovich Sobolev.

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Quasiconformal Mappings And Sobolev Spaces

Stanislav HencI, Pekka Koskela



Quasiconformal Mappings And Sobolev Spaces:

Quasiconformal Mappings and Sobolev Spaces V.M. Gol'dshtein, Yu.G. Reshetnyak, 1990-02-28 A study of the interconnection between Sobolev spaces geometric classes of mappings quasiconformal and quasiisometric and nonlinear capacity Chapter 1 introduces the terminology and auxiliary results used Chapter 2 deals with the foundations of the theory of classes of functions with generalized derivatives and discusses in detail methods of **Quasiconformal Mappings and Sobolev Spaces** V M Gol'dshtein, Yu G Reshetnyak, 1990-02-28 *Quasiconformal Mappings and Sobolev Spaces* V.M.

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Differential Equations and Quasiconformal Mappings in the Plane Kari Astala, Tadeusz Iwaniec, Gaven Martin, 2008-12-29 This book explores the most recent developments in the theory of planar quasiconformal mappings with a particular focus on the interactions with partial differential equations and nonlinear analysis It gives a thorough and modern approach to the classical theory and presents important and compelling applications across a spectrum of mathematics dynamical systems singular integral operators inverse problems the geometry of mappings and the calculus of variations It also gives an account of recent advances in harmonic analysis and their applications in the geometric theory of mappings The book explains that the existence regularity and singular set structures for second order divergence type equations the most important class of PDEs in applications are determined by the mathematics underpinning the geometry structure and dimension of fractal sets moduli spaces of Riemann surfaces and conformal dynamical systems These topics are inextricably linked by the theory of quasiconformal mappings Further the interplay between them allows the authors to extend classical results to more general settings for wider applicability providing new and often optimal answers to questions of existence regularity and geometric properties of solutions to nonlinear systems in both elliptic and degenerate elliptic settings

Sobolev Spaces in Mathematics I Vladimir Maz'ya, 2008-12-02 This volume mark s the centenary of the birth of the outstanding mathematician of the 20th century Sergey Sobolev It includes new results on the latest topics of the theory of Sobolev spaces partial differential equations analysis and mathematical physics Sobolev Spaces on Metric Measure Spaces Juha Heinonen, Pekka Koskela, Nageswari Shanmugalingam, Jeremy T. Tyson, 2015-02-05 Analysis on metric spaces

emerged in the 1990s as an independent research field providing a unified treatment of first order analysis in diverse and potentially nonsmooth settings Based on the fundamental concept of upper gradient the notion of a Sobolev function was formulated in the setting of metric measure spaces supporting a Poincar inequality This coherent treatment from first principles is an ideal introduction to the subject for graduate students and a useful reference for experts It presents the foundations of the theory of such first order Sobolev spaces then explores geometric implications of the critical Poincar inequality and indicates numerous examples of spaces satisfying this axiom A distinguishing feature of the book is its focus on vector valued Sobolev spaces The final chapters include proofs of several landmark theorems including Cheeger's stability theorem for Poincar inequalities under Gromov Hausdorff convergence and the Keith Zhong self improvement theorem for Poincar inequalities

Moduli in Modern Mapping Theory Olli Martio, Vladimir Ryazanov, Uri Srebro, Eduard Yakubov, 2008-11-09 Based on recent research papers this book presents a modern account of mapping theory with emphasis on quasiconformal mapping and its generalizations It contains an extensive bibliography

Lectures on Analysis on Metric Spaces Juha Heinonen, 2012-12-06 Analysis in spaces with no a priori smooth structure has progressed to include concepts from the first order calculus In particular there have been important advances in understanding the infinitesimal versus global behavior of Lipschitz functions and quasiconformal mappings in rather general settings abstract Sobolev space theories have been instrumental in this development The purpose of this book is to communicate some of the recent work in the area while preparing the reader to study more substantial related articles The material can be roughly divided into three different types classical standard but sometimes with a new twist and recent The author first studies basic covering theorems and their applications to analysis in metric measure spaces This is followed by a discussion on Sobolev spaces emphasizing principles that are valid in larger contexts The last few sections of the book present a basic theory of quasisymmetric maps between metric spaces Much of the material is relatively recent and appears for the first time in book format There are plenty of exercises The book is well suited for self study or as a text in a graduate course or seminar The material is relevant to anyone who is interested in analysis and geometry in nonsmooth settings

Conformal Geometry and Quasiregular Mappings Matti Vuorinen, 2006-11-15 This book is an introduction to the theory of spatial quasiregular mappings intended for the uninitiated reader At the same time the book also addresses specialists in classical analysis and in particular geometric function theory The text leads the reader to the frontier of current research and covers some most recent developments in the subject previously scattered through the literature A major role in this monograph is played by certain conformal invariants which are solutions of extremal problems related to extremal lengths of curve families These invariants are then applied to prove sharp distortion theorems for quasiregular mappings One of these extremal problems of conformal geometry generalizes a classical two dimensional problem of O Teichmüller The novel feature of the exposition is the way in which conformal invariants are applied and the sharp results obtained should be of considerable interest even in the two

dimensional particular case This book combines the features of a textbook and of a research monograph it is the first introduction to the subject available in English contains nearly a hundred exercises a survey of the subject as well as an extensive bibliography and finally a list of open problems Complex Analysis and Dynamical Systems III Mark L'vovich Agranovskii, 2008 The papers in this volume cover a wide variety of topics in the geometric theory of functions of one and several complex variables including univalent functions conformal and quasiconformal mappings minimal surfaces and dynamics in infinite dimensional spaces In addition there are several articles dealing with various aspects of approximation theory and partial differential equations Taken together the articles collected here provide the reader with a panorama of activity in complex analysis drawn by a number of leading figures in the field Harmonic Analysis and Partial Differential Equations Anatoly Golberg, Peter Kuchment, David Shoikhet, 2023-03-25 Over the course of his distinguished career Vladimir Maz'ya has made a number of groundbreaking contributions to numerous areas of mathematics including partial differential equations function theory and harmonic analysis The chapters in this volume compiled on the occasion of his 80th birthday are written by distinguished mathematicians and pay tribute to his many significant and lasting achievements **Harmonic Quasiconformal Mappings and Hyperbolic Type Metrics** Vesna Todorčević, 2019-07-24 The book presents a research area in geometric function theory concerned with harmonic quasiconformal mappings and hyperbolic type metrics defined on planar and multidimensional domains The classes of quasiconformal and quasiregular mappings are well established areas of study in this field as these classes are natural and fruitful generalizations of the class of analytic functions in the planar case The book contains many concrete examples as well as detailed proofs and explanations of motivations behind given results gradually bringing the reader to the forefront of current research in the area This monograph was written for a wide readership from graduate students of mathematical analysis to researchers working in this or related areas of mathematics who want to learn the tools or work on open problems listed in various parts of the book **Handbook of Complex Analysis** Reiner Kuhnau, 2004-12-09 Geometric Function Theory is that part of Complex Analysis which covers the theory of conformal and quasiconformal mappings Beginning with the classical Riemann mapping theorem there is a lot of existence theorems for canonical conformal mappings On the other side there is an extensive theory of qualitative properties of conformal and quasiconformal mappings concerning mainly a priori estimates so called distortion theorems including the Bieberbach conjecture with the proof of the Branges Here a starting point was the classical Schwarz lemma and then Koebe's distortion theorem There are several connections to mathematical physics because of the relations to potential theory in the plane The Handbook of Geometric Function Theory contains also an article about constructive methods and further a Bibliography including applications eg to electrostatic problems heat conduction potential flows in the plane A collection of independent survey articles in the field of Geometric Function Theory Existence theorems and qualitative properties of conformal and quasiconformal mappings A bibliography including many hints to applications in electrostatics heat

conduction potential flows in the plane Lectures on Mappings of Finite Distortion Stanislav Hencl, Pekka Koskela, 2014-01-24 In this book we introduce the class of mappings of finite distortion as a generalization of the class of mappings of bounded distortion Connections with models of nonlinear elasticity are also discussed We study continuity properties behavior of our mappings on null sets topological properties like openness and discreteness regularity of the potential inverse mappings and many other aspects *Complex Analysis and Dynamical Systems IV* Mark L'vovich Agranovskii, 2011 The papers in this volume cover a wide variety of topics in the geometric theory of functions of one and several complex variables including univalent functions conformal and quasiconformal mappings and dynamics in infinite dimensional spaces In addition there are several articles dealing with various aspects of Lie groups control theory and optimization Taken together the articles provide the reader with a panorama of activity in complex analysis and quasiconformal mappings drawn by a number of leading figures in the field The companion volume Contemporary Mathematics Volume 554 is devoted to general relativity geometry and PDE **Principles of Functional Analysis** Martin Schechter, 2001-11-13 This excellent book provides an elegant introduction to functional analysis carefully selected problems This is a nicely written book of great value for stimulating active work by students It can be strongly recommended as an undergraduate or graduate text or as a comprehensive book for self study European Mathematical Society Newsletter Functional analysis plays a crucial role in the applied sciences as well as in mathematics It is a beautiful subject that can be motivated and studied for its own sake In keeping with this basic philosophy the author has made this introductory text accessible to a wide spectrum of students including beginning level graduates and advanced undergraduates The exposition is inviting following threads of ideas describing each as fully as possible before moving on to a new topic Supporting material is introduced as appropriate and only to the degree needed Some topics are treated more than once according to the different contexts in which they arise The prerequisites are minimal requiring little more than advanced calculus and no measure theory The text focuses on normed vector spaces and their important examples Banach spaces and Hilbert spaces The author also includes topics not usually found in texts on the subject This Second Edition incorporates many new developments while not overshadowing the book's original flavor Areas in the book that demonstrate its unique character have been strengthened In particular new material concerning Fredholm and semi Fredholm operators is introduced requiring minimal effort as the necessary machinery was already in place Several new topics are presented but relate to only those concepts and methods emanating from other parts of the book These topics include perturbation classes measures of noncompactness strictly singular operators and operator constants Overall the presentation has been refined clarified and simplified and many new problems have been added The book is recommended to advanced undergraduates graduate students and pure and applied research mathematicians interested in functional analysis and operator theory **Function Spaces, Theory and Applications** Ilia Binder, Damir Kinzhebulatov, Javad Mashreghi, 2023-12-11 The focus program on

Analytic Function Spaces and their Applications took place at Fields Institute from July 1st to December 31st 2021 Hilbert spaces of analytic functions form one of the pillars of complex analysis These spaces have a rich structure and for more than a century have been studied by many prominent mathematicians They also have several essential applications in other fields of mathematics and engineering e g robust control engineering signal and image processing and theory of communication The most important Hilbert space of analytic functions is the Hardy class H^2 However its close cousins e g the Bergman space A^2 the Dirichlet space D the model subspaces K_t and the de Branges Rovnyak spaces H_b have also been the center of attention in the past two decades Studying the Hilbert spaces of analytic functions and the operators acting on them as well as their applications in other parts of mathematics or engineering were the main subjects of this program During the program the world leading experts on function spaces gathered and discussed the new achievements and future venues of research on analytic function spaces their operators and their applications in other domains With more than 250 hours of lectures by prominent mathematicians a wide variety of topics were covered More explicitly there were mini courses and workshops on Hardy Spaces Dirichlet Spaces Bergman Spaces Model Spaces Interpolation and Sampling Riesz Bases Frames and Signal Processing Bounded Mean Oscillation de Branges Rovnyak Spaces Operators on Function Spaces Truncated Toeplitz Operators Blaschke Products and Inner Functions Discrete and Continuous Semigroups of Composition Operators The Corona Problem Non commutative Function Theory Drury Arveson Space and Convergence of Scattering Data and Non linear Fourier Transform At the end of each week there was a high profile colloquium talk on the current topic The program also contained two semester long advanced courses on Schramm Loewner Evolution and Lattice Models and Reproducing Kernel Hilbert Space of Analytic Functions The current volume features a more detailed version of some of the talks presented during the program

Geometric Function Theory and Non-linear Analysis Tadeusz Iwaniec, Gaven Martin, 2001 This unique book explores the connections between the geometry of mappings and many important areas of modern mathematics such as Harmonic and non linear Analysis the theory of Partial Differential Equations Conformal Geometry and Topology Much of the book is new It aims to provide students and researchers in many areas with a comprehensive and up to date account and an overview of the subject as a whole

Complex Analysis and Dynamical Systems II Lawrence Allen Zalcman, Mark L'vovich Agranovskii, Lavi Karp, David Shoikhet, 2005 This volume is a collection of papers reflecting the conference held in Nahariya Israel in honor of Professor Lawrence Zalcman's sixtieth birthday The papers many written by leading authorities range widely over classical complex analysis of one and several variables differential equations and integral geometry Topics covered include but are not limited to these areas within the theory of functions of one complex variable complex dynamics elliptic functions Kleinian groups quasiconformal mappings Tauberian theorems univalent functions and value distribution theory Altogether the papers in this volume provide a comprehensive overview of activity in complex analysis at the beginning of the twenty first century and testify to the continuing vitality of the interplay between

classical and modern analysis It is suitable for graduate students and researchers interested in computer analysis and differential geometry Information for our distributors This book is co published with Bar Ilan University **Quasiregular Mappings** Seppo Rickman, 2012-12-06 Quasiregular Mappings extend quasiconformal theory to the noninjective case They give a natural and beautiful generalization of the geometric aspects of the theory of analytic functions of one complex variable to Euclidean n space or more generally to Riemannian n manifolds This book is a self contained exposition of the subject A broad spectrum of results of both analytic and geometric character are presented and the methods vary accordingly The main tools are the variational integral method and the extremal length method both of which are thoroughly developed here Reshetnyak's basic theorem on discreteness and openness is used from the beginning but the proof by means of variational integrals is postponed until near the end Thus the method of extremal length is being used at an early stage and leads among other things to geometric proofs of Picard type theorems and a defect relation which are some of the high points of the present book

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