

## Chapter 2

# Composition Operators on Second-Order Cesàro Function Spaces



Metin Başarır, Serkan Demiriz, and Emrah Evren Kara

**Abstract** This paper obtains some results regarding the Fredholmness, compactness, and boundedness of composition operators defined on the second-order Cesàro function spaces proposed by Braha. Then, we compute the composition operators' essential norm.

**Keywords** Cesàro function spaces · Essential norm · Fredholmness · Compactness · Boundedness · Composition operators

### 2.1 Introduction

Let  $(\Pi, \omega, \eta)$  be a  $\sigma$ -finite measure space and  $L^0(\Pi)$  denote the set of all equivalence classes of complex-valued measurable functions defined on  $\Pi$  where  $\Pi = [0, 1]$  or  $\Pi = [0, \infty)$ . The Cesàro function space, denoted by  $Ces_p(\Pi)$ , is defined as follows:

$$Ces_p(\Pi) = \left\{ \xi \in L^0(\Pi) : \int_{\Pi} \left( \frac{1}{x} \int_0^x |\xi(t)| d\eta(t) \right)^p d\eta(x) < \infty \right\} \quad (1 \leq p \leq \infty).$$

In [1], Maligranda and Astashkin proved that the Cesàro function space is a Banach space with the norm

$$\|\xi\|_1 = \left\{ \int_{\Pi} \left( \frac{1}{x} \int_0^x |\xi(t)| d\eta(t) \right)^p d\eta(x) \right\}^{1/p} \quad 1 \leq p < \infty$$

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# Composition Operators On Function Spaces

**Nicola Arcozzi, Richard Rochberg, Eric  
T. Sawyer, Brett D. Wick**



## **Composition Operators On Function Spaces:**

**Composition Operators on Function Spaces** R.K. Singh, J.S. Manhas, 1993-11-03 This volume of the Mathematics Studies presents work done on composition operators during the last 25 years. Composition operators form a simple but interesting class of operators having interactions with different branches of mathematics and mathematical physics. After an introduction, the book deals with these operators on  $L_p$  spaces. This study is useful in measurable dynamics, ergodic theory, classical mechanics, and Markov process. The composition operators on functional Banach spaces including Hardy spaces are studied in chapter III. This chapter makes contact with the theory of analytic functions of complex variables. Chapter IV presents a study of these operators on locally convex spaces of continuous functions making contact with topological dynamics. In the last chapter of the book, some applications of composition operators in isometries, ergodic theory, and dynamical systems are presented. An interesting interplay of algebra, topology, and analysis is displayed. This comprehensive and up to date study of composition operators on different function spaces should appeal to research workers in functional analysis and operator theory, post graduate students of mathematics and statistics as well as to physicists and engineers.

**Studies on Composition Operators and Function Spaces** Marko Kotilainen, 2007 This survey part of the thesis contains some background to the series of studies on composition operators and function spaces. Bounded and compact composition operators are studied in analytic  $Q_k$  type spaces and in some real function spaces. So called Bloch-Sobolev spaces are introduced. An asymptotic formula for the essential norm of the composition operator mapping into  $Q_{k,p,q}$  is established. Carleson measures are studied in higher dimensions and used in the study of hyperbolic harmonic function spaces. A short summary of the articles is included.

**Operator Theory in Function Spaces** Kehe Zhu, 2007 This book covers Toeplitz operators, Hankel operators, and composition operators on both the Bergman space and the Hardy space. The setting is the unit disk and the main emphasis is on size estimates of these operators, boundedness, compactness, and membership in the Schatten classes. Most results concern the relationship between operator theoretic properties of these operators and function theoretic properties of the inducing symbols. Thus a good portion of the book is devoted to the study of analytic function spaces such as the Bloch space, Besov spaces, and BMOA whose elements are to be used as symbols to induce the operators we study. The book is intended for both research mathematicians and graduate students in complex analysis and operator theory. The prerequisites are minimal; a graduate course in each of real analysis, complex analysis, and functional analysis should sufficiently prepare the reader for the book. Exercises and bibliographical notes are provided at the end of each chapter. These notes will point the reader to additional results and problems. Kehe Zhu is a professor of mathematics at the State University of New York at Albany. His previous books include *Theory of Bergman Spaces* Springer 2000 with H. Hedenmalm and B. Korenblum, and *Spaces of Holomorphic Functions in the Unit Ball* Springer 2005. His current research interests are holomorphic function spaces and operators acting on them.

**Composition Operators on Spaces**

**of Analytic Functions** Carl C. Cowen Jr., 2019-03-04 The study of composition operators lies at the interface of analytic function theory and operator theory *Composition Operators on Spaces of Analytic Functions* synthesizes the achievements of the past 25 years and brings into focus the broad outlines of the developing theory It provides a comprehensive introduction to the linear operators of composition with a fixed function acting on a space of analytic functions This new book both highlights the unifying ideas behind the major theorems and contrasts the differences between results for related spaces Nine chapters introduce the main analytic techniques needed Carleson measure and other integral estimates linear fractional models and kernel function techniques and demonstrate their application to problems of boundedness compactness spectra normality and so on of composition operators Intended as a graduate level textbook the prerequisites are minimal Numerous exercises illustrate and extend the theory For students and non students alike the exercises are an integral part of the book By including the theory for both one and several variables historical notes and a comprehensive bibliography the book leaves the reader well grounded for future research on composition operators and related areas in operator or function theory

**Compact Weighted Composition Operators on Function Spaces** Hiroyuki Takagi, 1992 *Small Composition Operators on Analytic Vector-valued Function Spaces* P. Liu, E. Saksman, Hans-Olav Tylli, 1996 *Studies on Composition Operators* Rocky Mountain Mathematics Consortium, 1998 This book reflects the proceedings of the 1996 Rocky Mountain Mathematics Consortium conference on Composition Operators on Spaces of Analytic Functions held at the University of Wyoming The readers will find here a collection of high quality research and expository articles on composition operators in one and several variables The book highlights open questions and new advances in the classical areas and promotes topics which are left largely untreated in the existing texts In the past two decades the study of composition operators has experienced tremendous growth Many connections between the study of these operators on various function spaces and other branches of analysis have been established Advances in establishing criteria for membership in different operator classes have led to progress in the study of the spectra adjoints and iterates of these operators More recently connections between these operators and the study of the invariant subspace problem functional equations and dynamical systems have been exploited *Function Spaces* Krzysztof Jarosz, 2007 This book consists of contributions by the participants of the Fifth Conference on Function Spaces held at Southern Illinois University in May of 2006 The papers cover a broad range of topics including spaces and algebras of analytic functions of one and of many variables and operators on such spaces  $L_p$  spaces spaces of Banach valued functions isometries of function spaces geometry of Banach spaces and other related subjects The goal of the conference was to bring together mathematicians interested in various problems related to function spaces and to facilitate the exchange of ideas between people working on similar problems Hence the majority of papers in this book are accessible to non experts Some articles contain expositions of known results and discuss open problems others contain new results **Function Spaces in Analysis** Krzysztof Jarosz, 2015-07-28 This volume contains the proceedings of the Seventh

Conference on Function Spaces which was held from May 20-24, 2014 at Southern Illinois University at Edwardsville. The papers cover a broad range of topics including spaces and algebras of analytic functions of one and of many variables and operators on such spaces, spaces of integrable functions, spaces of Banach valued functions, isometries of function spaces, geometry of Banach spaces and other related subjects. Lectures on Analytic Function Spaces and their Applications Javad Mashreghi, 2023-10-13. 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 have essential applications in other fields of mathematics and engineering. The most important Hilbert space of analytic functions is the Hardy class  $H^2$ . However, its close cousins, the Bergman space  $A^2$ , the Dirichlet space  $\mathcal{D}$ , the model subspaces  $K_t$  and the de Branges-Rovnyak spaces  $H(b)$  have also garnered attention in recent decades. Leading experts on function spaces gathered and discussed new achievements and future venues of research on analytic function spaces, their operators and their applications in other domains. With over 250 hours of lectures by prominent mathematicians, the program spanned a wide variety of topics. More explicitly, there were courses and workshops on Interpolation and Sampling, Riesz Bases, Frames and Signal Processing, Bounded Mean Oscillation, de Branges-Rovnyak Spaces, Blaschke Products and Inner Functions, and Convergence of Scattering Data and Non-linear Fourier Transform among others. At the end of each week, there was a high profile colloquium talk on the current topic. The program also contained two advanced courses on Schramm-Loewner Evolution and Lattice Models and Reproducing Kernel Hilbert Space of Analytic Functions. This volume features the courses given on Hardy Spaces, Dirichlet Spaces, Bergman Spaces, Model Spaces, Operators on Function Spaces, Truncated Toeplitz Operators, Semigroups of weighted composition operators on spaces of holomorphic functions, the Corona Problem, Non-commutative Function Theory and Drury-Arveson Space. This volume is a valuable resource for researchers interested in analytic function spaces.

**Composition Operators on Vector-valued BMOA and Related Function Spaces** Jussi Laitila, 2006.

**The Dirichlet Space and Related Function Spaces** Nicola Arcozzi, Richard Rochberg, Eric T. Sawyer, Brett D. Wick, 2019-09-03. The study of the classical Dirichlet space is one of the central topics on the intersection of the theory of holomorphic functions and functional analysis. It was introduced about 100 years ago and continues to be an area of active current research. The theory is related to such important themes as multipliers, reproducing kernels and Besov spaces among others. The authors present the theory of the Dirichlet space and related spaces starting with classical results and including some quite recent achievements like Dirichlet type spaces of functions in several complex variables and the corona problem. The first part of this book is an introduction to the function theory and operator theory of the classical Dirichlet space, a space of holomorphic functions on the unit disk defined by a smoothness criterion. The Dirichlet space is also a Hilbert space with a reproducing kernel and is the model for the dyadic Dirichlet space, a sequence space defined on the dyadic tree. These various

viewpoints are used to study a range of topics including the Pick property multipliers Carleson measures boundary values zero sets interpolating sequences the local Dirichlet integral shift invariant subspaces and Hankel forms Recurring themes include analogies sometimes weak and sometimes strong with the classical Hardy space and the analogy with the dyadic Dirichlet space The final chapters of the book focus on Besov spaces of holomorphic functions on the complex unit ball a class of Banach spaces generalizing the Dirichlet space Additional techniques are developed to work with the nonisotropic complex geometry including a useful invariant definition of local oscillation and a sophisticated variation on the dyadic Dirichlet space Descriptions are obtained of multipliers Carleson measures interpolating sequences and multiplier interpolating sequences estimates are obtained to prove corona theorems

**Function Spaces and Operators between them** José Bonet, David Jornet, Pablo Sevilla-Peris, 2023-10-28 The aim of this work is to present in a unified and reasonably self contained way certain aspects of functional analysis which are needed to treat function spaces whose topology is not derived from a single norm their topological duals and operators between those spaces We treat spaces of continuous analytic and smooth functions as well as sequence spaces Operators of differentiation integration composition multiplication and partial differential operators between those spaces are studied A brief introduction to Laurent Schwartz's theory of distributions and to Lars Hörmander's approach to linear partial differential operators is presented The novelty of our approach lies mainly on two facts First of all we show all these topics together in an accessible way stressing the connection between them Second we keep it always at a level that is accessible to beginners and young researchers Moreover parts of the book might be of interest for researchers in functional analysis and operator theory Our aim is not to build and describe a whole complete theory but to serve as an introduction to some aspects that we believe are interesting We wish to guide any reader that wishes to enter in some of these topics in their first steps Our hope is that they learn interesting aspects of functional analysis and become interested to broaden their knowledge about function and sequence spaces and operators between them The text is addressed to students at a master level or even undergraduate at the last semesters since only knowledge on real and complex analysis is assumed We have intended to be as self contained as possible and wherever an external citation is needed we try to be as precise as we can Our aim is to be an introduction to topics in or connected with different aspects of functional analysis Many of them are in some sense classical but we tried to show a unified direct approach some others are new This is why parts of these lectures might be of some interest even for researchers in related areas of functional analysis or operator theory There is a full chapter about transitive and mean ergodic operators on locally convex spaces This material is new in book form It is a novel approach and can be of interest for researchers in the area

Substitution Operators on Some Function Spaces Kuldeep Raj, 2010-08 The studies involving composition of functions have been pursued for a long time but the study of linear operators induced by composition with fixed functions has relatively a short story In the beginning composition operators were known as substitution operators The adjoint of the unilateral shift operator on  $\ell^2(\mathbb{N})$  and bilateral shift operator on  $\ell^2(\mathbb{Z})$

DEGREES  $2\mathbb{Z}$  are well studied examples of composition operators. The systematic study of composition substitution operators was started by Eric A Nordgren in 1968. These operators have been the subject matter of study over the past 40 years. The applications of substitution operators are very much used in engineering.

Operator-weighted Composition Operators on Vector-valued Analytic Function Spaces Jussi Laitila, Hans-Olav Tylli, 2008

*Function Spaces, Proceedings Of The Sixth Conference* Ryszard Grzaslewicz, Henryk Hudzik, Julian Musielak, Czesław Ryll-nardzewski, 2003-04-03. The papers included in this volume deal with the following topics: convex analysis, operator theory, interpolation theory, theory of real functions, theory of analytic functions, bifurcation theory, Fourier analysis, functional analysis, measure theory, geometry of Banach spaces, history of mathematics.

*Mobius Invariant QK Spaces* Hasi Wulan, Kehe Zhu, 2017-07-03. This monograph summarizes the recent major achievements in Möbius invariant QK spaces. First introduced by Hasi Wulan and his collaborators, the theory of QK spaces has developed immensely in the last two decades and the topics covered in this book will be helpful to graduate students and new researchers interested in the field. Featuring a wide range of subjects including an overview of QK spaces, QK Teichmüller spaces, Carleson measures and analysis of weight functions, this book serves as an important resource for analysts interested in this area of complex analysis. Notes, numerous exercises and a comprehensive up to date bibliography provide an accessible entry to anyone with a standard graduate background in real and complex analysis.

Problems and Recent Methods in Operator Theory Fernanda Botelho, Raena King, T. S. S. R. K. Rao, 2017-04-18. This volume contains the proceedings of the Workshop on Problems and Recent Methods in Operator Theory held at the University of Memphis, Memphis, TN, from October 15-16, 2015, and the AMS Special Session on Advances in Operator Theory and Applications in Memory of James Jamison held at the University of Memphis, Memphis, TN, from October 17-18, 2015. Operator theory is at the root of several branches of mathematics and offers a broad range of challenging and interesting research problems. It also provides powerful tools for the development of other areas of science including quantum theory, physics and mechanics. Isometries have applications in solid state physics. Hermitian operators play an integral role in quantum mechanics, very much due to their nice spectral properties. These powerful connections demonstrate the impact of operator theory in various branches of science. The articles in this volume address recent problems and research advances in operator theory. Highlighted topics include spectral, structural and geometric properties of special types of operators on Banach spaces with emphasis on isometries, weighted composition operators, multi-circular projections on function spaces as well as vector-valued function spaces and spaces of analytic functions. This volume gives a succinct overview of state-of-the-art techniques from operator theory as well as applications to classical problems and long-standing open questions.

*Function Spaces* Ryszard Grzysiewicz, 2003. The papers included in this volume deal with the following topics: convex analysis, operator theory, interpolation theory, theory of real functions, theory of analytic functions, bifurcation theory, Fourier analysis, functional analysis, measure theory, geometry of Banach spaces, history of mathematics.

**Functional Analysis** Klaus D.

Bierstedt, Albrecht Pietsch, Wolfgang M. Ruess, Dietmar Vogt, 1993-09-16 These proceedings from the Symposium on Functional Analysis explore advances in the usually separate areas of semigroups of operators and evolution equations geometry of Banach spaces and operator ideals and Frechet spaces with applications in partial differential equations



## Reviewing **Composition Operators On Function Spaces**: Unlocking the Spellbinding Force of Linguistics

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hypothesize what might have been the cause of this die off there was a large wolf die off after 1980

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