

GENERALIZATIONS OF THE PERRON-FROBENIUS THEOREM FOR NONLINEAR MAPS

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ABSTRACT. Let $K^n = \{x \in \mathbb{R}^n \mid x_i \geq 0, 1 \leq i \leq n\}$ and suppose that $f : K^n \rightarrow K^n$ is nonexpansive with respect to the l_1 -norm, $\|x\|_1 = \sum_{i=1}^n x_i$, and $f(0) = 0$. It is known (see [1]) that for every $x \in K^n$ there exists a periodic point $\xi = \xi_x \in K^n$ (so $f^p(\xi) = \xi$ for some minimal positive integer $p = p_\xi$) and $f^k(x)$ approaches $\{f^j(\xi) \mid 0 \leq j < p\}$ as k tends to infinity. In a previous paper [13] the set $P_2(n)$ of positive integers p for which there exists a map f as above and a periodic point $\xi \in K^n$ of minimal period p was related to the idea of "admissible arrays" and a set $Q(n)$ determined by certain arithmetical and combinatorial constraints. In a sequel to this paper [14] it is proved that $P_2(n) = Q(n)$ for all n , but the computation of $Q(n)$ is highly nontrivial. Here we derive a variety of theorems about admissible arrays and use these theorems to compute $Q(n)$ explicitly for $n \leq 50$ and prove that $P(n) = P_2(n) = Q(n)$ for $n \leq 50$, where $P(n)$ is a naturally occurring set defined below.

1. INTRODUCTION

Suppose that $f : \mathbb{R}^n \rightarrow \mathbb{R}^n$ is a linear mapping such that $f(K^n) \subset K^n$ and $\|f(x) - f(y)\|_1 \leq \|x - y\|_1$ for all $x, y \in \mathbb{R}^n$. Equivalently, f is given by an $n \times n$ matrix $A = (a_{ij})$ with $a_{ij} \geq 0$ for all i and j and $\sum_{i=1}^n a_{ij} \leq 1$ for $1 \leq j \leq n$. The Perron-Frobenius theory of nonnegative matrices implies that for every $x \in K^n$ there exists a minimal positive integer p and a point $\xi_x = \xi \in K^n$ such that

$$\lim_{j \rightarrow \infty} f^{jp}(x) = \xi, \quad \text{and } f^p(\xi) = \xi, \quad f^i(\xi) \neq \xi \text{ for } 1 \leq i < p.$$

Furthermore, Perron-Frobenius theory implies that p is the least common multiple of some set of positive integers whose sum is less than or equal to n , so p is the order of some element of the symmetric group on n letters. (For completeness we shall sketch a proof of a more general result in Section 9.) Conversely, every element σ of the symmetric group on n letters generates a linear map as above and has a periodic point of period equal to its order. Thus, in the linear case, it is possible to describe exactly the set of possible periods p . However, one should note that even in the linear case the explicit computation of the set of possible periods is not entirely trivial for large n ; and finding asymptotics and explicit upper bounds for the largest order of an element of the symmetric groups on n letters involves the prime number theorem [6, 7].

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Generalizations Of The Perron Frobenius Theorem For Nonlinear Maps:

Generalizations of the Perron-Frobenius Theorem for Nonlinear Maps Roger D. Nussbaum, Sjoerd M. Verduyn Lunel, 1999
The classical Frobenius Perron Theorem establishes the existence of periodic points of certain linear maps in \mathbb{R}^n . The authors present generalizations of this theorem to nonlinear maps. [Generalizations of the Perron-Frobenius Theorem for Nonlinear Maps](#) Roger D. Nussbaum, Sjoerd M. Verduyn Lunel, 1999 The classical Frobenius Perron Theorem establishes the existence of periodic points of certain linear maps in \mathbb{R}^n . The authors present generalizations of this theorem to nonlinear maps. **Generalizations of the Perron-Frobenius Theorem for Nonlinear Maps** Roger D. Nussbaum (wiskundige), 1996 *Nonlinear Perron-Frobenius Theory* Bas Lemmens, Roger Nussbaum, 2012-05-03 Guides the reader through the nonlinear Perron Frobenius theory introducing them to recent developments and challenging open problems. [Topics in Dynamics and Ergodic Theory](#) Sergey Bezuglyi, 2003-12-08 This book contains a collection of survey papers by leading researchers in ergodic theory low dimensional and topological dynamics and it comprises nine chapters on a range of important topics These include the role and usefulness of ultrafilters in ergodic theory topological dynamics and Ramsey theory topological aspects of kneading theory together with an analogous 2 dimensional theory called pruning the dynamics of Markov odometers Bratteli Vershik diagrams and orbit equivalence of non singular automorphisms geometric proofs of Mather's connecting and accelerating theorems recent results in one dimensional smooth dynamics periodic points of nonexpansive maps arithmetic dynamics the defect of factor maps entropy theory for actions of countable amenable groups. **Recent Developments in Optimization Theory and Nonlinear Analysis** Yair Censor, Simeon Reich, 1997 This volume contains the refereed proceedings of the special session on Optimization and Nonlinear Analysis held at the Joint American Mathematical Society Israel Mathematical Union Meeting which took place at the Hebrew University of Jerusalem in May 1995 Most of the papers in this book originated from the lectures delivered at this special session In addition some participants who didn't present lectures and invited speakers who were unable to attend contributed their work The fields of optimization theory and nonlinear analysis continue to be very active This book presents not only the wide spectrum and diversity of the results but also their manifold connections to other areas such as differential equations functional analysis operator theory calculus of variations numerical analysis and mathematical programming In reading this book one encounters papers that deal for example with convex quasiconvex and generalized convex functions fixed and periodic points fractional linear transformations moduli of convexity monotone operators Morse lemmas Navier Stokes equations nonexpansive maps nonsmooth analysis numerical stability products of projections steepest descent the Leray Schauder degree the turnpike property and variational inequalities. **Proper Maps of Toposes** Ieke Moerdijk, Jacob Johan Caspar Vermeulen, 2000 We develop the theory of compactness of maps between toposes together with associated notions of separatedness This theory is built around two versions of propriety for topos maps introduced here in a parallel fashion The

first giving what we simply call proper maps is a relatively weak condition due to Johnstone The second kind of proper maps here called tidy satisfy a stronger condition due to Tierney and Lindgren Various forms of the Beck Chevalley condition for lax fibered product squares of toposes play a central role in the development of the theory Applications include a version of the Reeb stability theorem for toposes a characterization of hyperconnected Hausdorff toposes as classifying toposes of compact groups and of strongly Hausdorff coherent toposes as classifying toposes of profinite groupoids Our results also enable us to develop further particular aspects of the factorization theory of geometric morphisms studied by Johnstone Our final application is a so called lax descent theorem for tidy maps between toposes This theorem implies the lax descent theorem for coherent toposes conjectured by Makkai and proved earlier by Zawadowski

The Defect Relation of Meromorphic Maps on Parabolic Manifolds George Lawrence Ashline, 1999 This book is intended for graduate students and research mathematicians working in several complex variables and analytic spaces

Tensor Analysis Liqun Qi, Ziyang Luo, 2017-04-19 Tensors or hypermatrices are multi arrays with more than two indices In the last decade or so many concepts and results in matrix theory some of which are nontrivial have been extended to tensors and have a wide range of applications for example spectral hypergraph theory higher order Markov chains polynomial optimization magnetic resonance imaging automatic control and quantum entanglement problems The authors provide a comprehensive discussion of this new theory of tensors Tensor Analysis Spectral Theory and Special Tensors is unique in that it is the first book on these three subject areas spectral theory of tensors the theory of special tensors including nonnegative tensors positive semidefinite tensors completely positive tensors and copositive tensors and the spectral hypergraph theory via tensors

An Ergodic IP Polynomial Szemerédi Theorem Vitaly Bergelson, Randall McCutcheon, 2000 The authors prove a polynomial multiple recurrence theorem for finitely many commuting measure preserving transformations of a probability space extending a polynomial Szemerédi theorem appearing in BL1 The linear case is a consequence of an ergodic IP Szemerédi theorem of Furstenberg and Katznelson FK2 Several applications to the fine structure of recurrence in ergodic theory are given some of which involve weakly mixing systems for which we also prove a multiparameter weakly mixing polynomial ergodic theorem The techniques and apparatus employed include a polynomialization of an IP structure theory developed in FK2 an extension of Hindman's theorem due to Milliken and Taylor M T a polynomial version of the Hales Jewett coloring theorem BL2 and a theorem concerning limits of polynomially generated IP systems of unitary operators BFM

Rational S^1 -Equivariant Stable Homotopy Theory John Patrick Campbell Greenlees, 1999 The memoir presents a systematic study of rational S^1 equivariant cohomology theories and a complete algebraic model for them It provides a classification of such cohomology theories in simple algebraic terms and a practical means of calculation The power of the model is illustrated by analysis of the Segal conjecture the behaviour of the Atiyah Hirzebruch spectral sequence the structure of S^1 equivariant K theory and the rational behaviour of cyclotomic spectra and the topological cyclic homology construction

The Theory of

Generalized Dirichlet Forms and Its Applications in Analysis and Stochastics Wilhelm Stannat, 1999 This text explores the theory of generalized Dirichlet Forms along with its applications for analysis and stochastics Examples are provided

Inverse Invariant Theory and Steenrod Operations Mara D. Neusel, 2000 This book is intended for researchers and graduate students in commutative algebra algebraic topology and invariant theory *Equivariant E^* -Theory for*

C^ -Algebras* Erik Guentner, Nigel Higson, Jody Trout, 2000 This title examines the equivariant E theory for C^* algebra focusing on research carried out by Higson and Kasparov Let A and B be C^* algebras which are equipped with continuous actions of a second countable locally compact group G We define a notion of equivariant asymptotic morphism and use it to define equivariant E theory groups $EULG(A, B)$ which generalize the E theory groups of Connes and Higson We develop the basic properties of equivariant E theory including a composition product and six term exact sequences in both variables and apply our theory to the problem of calculating K theory for group C^* algebras Our main theorem gives a simple criterion for the assembly map of Baum and Connes to be an isomorphism The result plays an important role in the work of Higson and Kasparov on the Baum-Connes conjecture for groups which act isometrically and metrically properly on Hilbert space

Dynamical Zeta Functions, Nielsen Theory and Reidemeister Torsion Alexander Fel'shtyn, Alexander Fel'shtyn, 2000 In the paper we study new dynamical zeta functions connected with Nielsen fixed point theory The study of dynamical zeta functions is part of the theory of dynamical systems but it is also intimately related to algebraic geometry number theory topology and statistical mechanics The paper consists of four parts Part I presents a brief account of the Nielsen fixed point theory Part II deals with dynamical zeta functions connected with Nielsen fixed point theory Part III is concerned with analog of Dold congruences for the Reidemeister and Nielsen numbers In Part IV we explain how dynamical zeta functions give rise to the Reidemeister torsion a very important topological invariant which has useful applications in knots theory quantum field theory and dynamical systems *Special Groups* M. A. Dickmann, Francisco Miraglia, 2000 This monograph presents a

systematic study of Special Groups a first order universal existential axiomatization of the theory of quadratic forms which comprises the usual theory over fields of characteristic different from 2 and is dual to the theory of abstract order spaces The heart of our theory begins in Chapter 4 with the result that Boolean algebras have a natural structure of reduced special group More deeply every such group is canonically and functorially embedded in a certain Boolean algebra its Boolean hull This hull contains a wealth of information about the structure of the given special group and much of the later work consists in unveiling it Thus in Chapter 7 we introduce two series of invariants living in the Boolean hull which characterize the isometry of forms in any reduced special group While the multiplicative series expressed in terms of meet and symmetric difference constitutes a Boolean version of the Stiefel-Whitney invariants the additive series expressed in terms of meet and join which we call Horn-Tarski invariants does not have a known analog in the field case however the latter have a considerably more regular behaviour We give explicit formulas connecting both series and compute explicitly the invariants

for Pfister forms and their linear combinations In Chapter 9 we combine Boolean theoretic methods with techniques from Galois cohomology and a result of Voevodsky to obtain an affirmative solution to a long standing conjecture of Marshall concerning quadratic forms over formally real Pythagorean fields Boolean methods are put to work in Chapter 10 to obtain information about categories of special groups reduced or not And again in Chapter 11 to initiate the model theoretic study of the first order theory of reduced special groups where amongst other things we determine its model companion The first order approach is also present in the study of some outstanding classes of morphisms carried out in Chapter 5 e g the pure embeddings of special groups Chapter 6 is devoted to the study of special groups of continuous functions

Existence of the Sectional Capacity Robert Rumely, Chi Fong Lau, Robert Varley, 2000 In the case where the norms are induced by metrics on the fibres of a local system \mathcal{L} we establish the functoriality of the sectional capacity under base change pullbacks by finite surjective morphisms and products We study the continuity of $\int_X \gamma$ over \mathcal{L} under variation of the metric and line bundle and we apply this to show that the notion of v -adic sets in X of capacity 0 is well defined Finally we show that sectional capacities for arbitrary norms can be well approximated using objects of finite type

Multi-Interval Linear Ordinary Boundary Value Problems and Complex Symplectic Algebra William Norrie Everitt, Lawrence Markus, 2001 A multi interval quasi differential system $I_r M_r w_r$ in Ω consists of a collection of real intervals I_r as indexed by a finite or possibly infinite index set Ω where $\text{card } \Omega \geq \aleph_0$ is permissible on which are assigned ordinary or quasi differential expressions M_r generating unbounded operators in the Hilbert function spaces $L_r^2 \equiv L^2(I_r, w_r)$ where w_r are given non negative weight functions For each fixed r in Ω assume that M_r is Lagrange symmetric formally self adjoint on I_r and hence specifies minimal and maximal closed operators T_{0r} and T_{1r} respectively in L_r^2 However the theory does not require that the corresponding deficiency indices d_r and \bar{d}_r of T_{0r} are equal e g the symplectic excess $Ex_r = d_r - \bar{d}_r \neq 0$ in which case there will not exist any self adjoint extensions of T_{0r} in L_r^2 In this paper a system Hilbert space $\mathbf{H} = \sum_{r \in \Omega} L_r^2$ is defined even for non countable Ω with corresponding minimal and maximal system operators \mathbf{T}_0 and \mathbf{T}_1 in \mathbf{H} Then the system deficiency indices $d \pm \sum_{r \in \Omega} d_r \pm$ are equal system symplectic excess $Ex = 0$ if and only if there exist self adjoint extensions \mathbf{T} of \mathbf{T}_0 in \mathbf{H} The existence is shown of a natural bijective correspondence between the set of all such self adjoint extensions \mathbf{T} of \mathbf{T}_0 and the set of all complete Lagrangian subspaces \mathbf{L} of the system boundary complex symplectic space $\mathbf{S} = \mathbf{D} \mathbf{T}_1 \mathbf{D} \mathbf{T}_0$ This result generalizes the earlier symplectic version of the celebrated GKN Theorem for single interval systems to multi interval systems Examples of such complete Lagrangians for both finite and infinite dimensional complex symplectic \mathbf{S} illuminate new phenomena for the boundary value problems of multi interval systems These concepts have applications to many particle systems of quantum mechanics and to other physical problems

Categories of Operator Modules (Morita

Equivalence and Projective Modules) David P. Blecher, Paul S. Muhly, Vern I. Paulsen, 2000 We employ recent advances in the theory of operator spaces also known as quantized functional analysis to provide a context in which one can compare categories of modules over operator algebras that are not necessarily self adjoint We focus our attention on the category of Hilbert modules over an operator algebra and on the category of operator modules over an operator algebra The module operations are assumed to be completely bounded usually completely contractive We develop the notion of a Morita context between two operator algebras A and B This is a system $(A \rtimes B, B \rtimes A, \cdot, \cdot, \cdot, \cdot)$ consisting of the algebras two bimodules $A \rtimes B$ and $B \rtimes A$ and pairings \cdot, \cdot and \cdot, \cdot that induce complete isomorphisms between the balanced Haagerup tensor products $X \otimes_h B \rtimes A$ and $Y \otimes_h A \rtimes B$ and the algebras A and B respectively Thus formally a Morita context is the same as that which appears in pure ring theory The subtleties of the theory lie in the interplay between the pure algebra and the operator space geometry Our analysis leads to viable notions of projective operator modules and dual operator modules We show that two C^* algebras are Morita equivalent in our sense if and only if they are C^* algebraically strong Morita equivalent and moreover the equivalence bimodules are the same The distinctive features of the non self adjoint theory are illuminated through a number of examples drawn from complex analysis and the theory of incidence algebras over topological partial orders Finally an appendix provides links to the literature that developed since this Memoir was accepted for publication

Joint Hyponormality of Toeplitz Pairs Raúl E. Curto, U-yöng Yi, 2001 This work explores joint hyponormality of Toeplitz pairs Topics include hyponormality of Toeplitz pairs with one co ordinate a Toeplitz operator with analytic polynomial symbol hyponormality of trigonometric Toeplitz pairs and the gap between 2 hyponormality and subnormality

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