

Introduction to Topological Groups

Dikran Dikranjan

To the memory of Ivan Prodanov (1935 – 1985)

Abstract

These notes provide a brief introduction to topological groups with a special emphasis on Pontryagin-van Kampen's duality theorem for locally compact abelian groups. We give a completely self-contained elementary proof of the theorem following the line from [41, 46]. According to the classical tradition, the structure theory of the locally compact abelian groups is built parallelly.

1 Introduction

Let \mathcal{L} denote the category of locally compact abelian groups and continuous homomorphisms and let $\mathbb{T} = \mathbb{R}/\mathbb{Z}$ be the unit circle group. For $G \in \mathcal{L}$ denote by \widehat{G} the group of continuous homomorphisms (characters) $G \rightarrow \mathbb{T}$ equipped with the compact-open topology. Then the assignment

$$G \mapsto \widehat{G}$$

is a contravariant endofunctor $\widehat{} : \mathcal{L} \rightarrow \mathcal{L}$. The celebrated Pontryagin-van Kampen duality theorem ([97]) says that this functor is, up to natural equivalence, an involution i.e., $\widehat{\widehat{G}} \cong G$ (see Theorem 11.5.4 for more detail). Moreover, this functor sends compact groups to discrete ones and viceversa, i.e., it defines a duality between the subcategory \mathcal{C} of compact abelian groups and the subcategory \mathcal{D} of discrete abelian groups. This allows for a very efficient and fruitful tool for the study of compact abelian groups, reducing all problems to the related problems in the category of discrete groups. The reader is advised to give a look at the Mackey's beautiful survey [90] for the connection of characters and Pontryagin-van Kampen duality to number theory, physics and elsewhere. This duality inspired a huge amount of related research also in category theory, a brief comment on a specific categorical aspect (uniqueness and representability) can be found in §8.1 of the Appendix.

The aim of these notes is to provide a self-contained proof of this remarkable duality theorem, providing all necessary steps, including basic background on topological groups and the structure theory of locally compact abelian groups. Peter-Weyl's theorem asserting that the continuous characters of the compact abelian groups separate the points of the groups (see Theorem 10.3.1) is certainly the most important tool in proving the duality theorem. The usual proof of Peter-Weyl's theorem involves Haar integration in order to produce sufficiently many finite-dimensional unitary representations. In the case of abelian groups the irreducible ones turn out to be one-dimensional, i.e., characters. We prefer here a different approach. Namely, Peter-Weyl's theorem can be obtained as an immediate corollary of a theorem of Folner (Theorem 10.1.1) whose elementary proof uses nothing beyond elementary properties of the finite abelian groups, a local version of the Stone-Weierstraß approximation theorem proved in §2 and the Stone-Čech compactification of discrete spaces. As another application of Folner's theorem we describe the precompact groups (i.e., the subgroups of the compact groups) as having a topology generated by continuous characters. As a third application of Folner's theorem one can obtain the existence of the Haar integral on locally compact abelian groups for free (see [41, §2.4, Theorem 2.4.5], Corollary 10.4.17 settles the case of compact abelian groups).

The notes are organized as follows. In Section 2 we recall basic results and notions on abelian groups and general topology, which will be used in the rest of the paper. Section 3 contains background on topological groups, starting from scratch. Various ways of introducing a group topology are considered (§3.2), of which the prominent one is by means of characters (§3.2.3). In §4.3 we recall the construction of Protasov and Zelenyuk [104] of topologies arising from a given sequence that is required to be convergent to 0.

In §4.1 we discuss separation axioms and metrizable of topological groups. Connectedness and related properties in topological groups are discussed in §4.2.

In §5 the Markov's problems on the existence of non-discrete Hausdorff group topologies is discussed. In §5.1 we introduce two topologies, the Markov topology and the Zariski topology, that allow for an easier understanding of Markov's problems. In §5.2 we describe the Markov topology of the infinite permutation groups, while §5.3 contains the first two examples of non-topologizable groups, given by Shelah and Ol'shanskii, respectively. The problems arising in

An Introduction To Topological Groups

Morikuni Goto



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Introduction to Topological Groups Taqdir Husain, 2018-02-15 Concise treatment covers semitopological groups locally compact groups Harn measure and duality theory and some of its applications The volume concludes with a chapter that introduces Banach algebras 1966 edition **An Introduction to Topological Groups** Philip J. Higgins, 1974 The book is based on lecture courses given for the London M Sc degree in 1969 and 1972 and the treatment is more algebraic than usual

An Introduction to Topological Groups Philip J Higgins, 1974 **Topological Groups and Related Structures** A. V. Arkhangel'skii, Mikhail Tkachenko, 2008 This book presents a large amount of material both classic and recent on occasion unpublished about the relations of Algebra and Topology It therefore belongs to the area called Topological Algebra More specifically the objects of the study are subtle and sometimes unexpected phenomena that occur when the continuity meets and properly feeds an algebraic operation Such a combination gives rise to many classic structures including topological groups and semigroups paratopological groups etc Special emphasis is given to tracing the influence of compactness and its generalizations on the properties of an algebraic operation causing on occasion the automatic continuity of the operation The main scope of the book however is outside of the locally compact structures thus distinguishing the monograph from a series of more traditional textbooks The book is unique in that it presents very important material dispersed in hundreds of research articles not covered by any monograph in existence The reader is gently introduced to an amazing world at the interface of Algebra Topology and Set Theory He she will find that the way to the frontier of the knowledge is quite short almost every section of the book contains several intriguing open problems whose solutions can contribute significantly to the area **Introduction to Topological Groups** Philip J. Higgins, 1979 An introduction to topological groups Morikuni Goto, 1974 **Topological Groups and Related Structures, An Introduction to Topological Algebra.** Alexander Arhangel'skii, Mikhail Tkachenko, 2008-05-01 Algebra and topology the two fundamental domains of mathematics play complementary roles Topology studies continuity and convergence and provides a general framework to study the concept of a limit Much of topology is devoted to handling infinite sets and in itself the methods developed are qualitative and in a certain sense irrational algebra studies all kinds of operations and provides a basis for algorithms and calculations Very often the methods here are nitistic in nature Because of this difference in nature algebra and topology have a strong tendency to develop independently not in direct contact with each other However in applications in higher level domains of mathematics such as functional analysis dynamical systems representation theory and others topology and algebra come in contact most naturally Many of the most important objects of mathematics represent a blend of algebraic and of topological structures Topological functions spaces and linear topological spaces in general topological groups and topological fields transformation groups topological lattices are objects of this kind Very often an algebraic structure and a topology come naturally together this is the case when they are both determined by the nature of the elements of the set considered a group of transformations is a

typical example The rules that describe the relationship between a topology and an algebraic operation are almost always transparent and natural the operation has to be continuous jointly or separately

Topological Groups and the Pontryagin-van Kampen Duality Lydia Außenhofer, Dikran Dikranjan, Anna Giordano Bruno, 2021-11-22 This book provides an introduction to topological groups and the structure theory of locally compact abelian groups with a special emphasis on Pontryagin van Kampen duality including a completely self contained elementary proof of the duality theorem Further related topics and applications are treated in separate chapters and in the appendix

Topology George McCarty, 2006-01-03 Admirably meets the topology requirements for the pregraduate training of research mathematicians American Mathematical Monthly Topology sometimes described as rubber sheet geometry is crucial to modern mathematics and to many other disciplines from quantum mechanics to sociology This stimulating introduction to the field will give the student a familiarity with elementary point set topology including an easy acquaintance with the line and the plane knowledge often useful in graduate mathematics programs The book is not a collection of topics rather it early employs the language of point set topology to define and discuss topological groups These geometric objects in turn motivate a further discussion of set theoretic topology and of its applications in function spaces An introduction to homotopy and the fundamental group then brings the student's new theoretical knowledge to bear on very concrete problems the calculation of the fundamental group of the circle and a proof of the fundamental theorem of algebra Finally the abstract development is brought to satisfying fruition with the classification of topological groups by equivalence under local isomorphism Throughout the book there is a sustained geometric development a single thread of reasoning which unifies the topological course One of the special features of this work is its well chosen exercises along with a selection of problems in each chapter that contain interesting applications and further theory Careful study of the text and diligent performance of the exercises will enable the student to achieve an excellent working knowledge of topology and a useful understanding of its applications Moreover the author's unique teaching approach lends an extra dimension of effectiveness to the books Of particular interest is the remarkable pedagogy evident in this work The author converses with the reader on a personal basis He speaks with him questions him challenges him and best of all occasionally leaves him to his own devices American Scientist

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Introduction to topological groups Mikhail G. Tkachenko, 1998 *Topology* Olga Andreyev Carlisle, 1967 *An Introductory Examination of Topological Groups* Stephen Lyon Bascom, 1972 **Topological Groups** Nelson G. Markley, 2010-09-22 A user friendly introduction to metric and topological groups Topological Groups An Introduction provides a self contained presentation with an emphasis on important families of topological groups The book uniquely provides a modern and balanced presentation by using metric groups to present a substantive introduction to topics such as duality while also shedding light on more general results for topological groups Filling the need for a broad and accessible

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Reviews of Papers in Algebraic and Differential Topology, Topological Groups, and Homological Algebra Norman Earl Steenrod, 1968 **Pseudocompact Topological Spaces** Michael Hrušák, Ángel Tamariz-Mascarúa, Mikhail Tkachenko, 2018-07-19 This book intended for postgraduate students and researchers presents many results of historical importance on pseudocompact spaces In 1948 E Hewitt introduced the concept of pseudocompactness which generalizes a property of compact subsets of the real line A topological space is pseudocompact if the range of any real valued continuous function defined on the space is a bounded subset of the real line Pseudocompact spaces constitute a natural and fundamental class of objects in General Topology and research into their properties has important repercussions in diverse branches of Mathematics such as Functional Analysis Dynamical Systems Set Theory and Topological Algebraic structures The collection of authors of this volume include pioneers in their fields who have written a comprehensive explanation on this subject In addition the text examines new lines of research that have been at the forefront of mathematics There is as yet no text that systematically compiles and develops the extensive theory of pseudocompact spaces making this book an essential asset for anyone in the field of topology

Introduction to Topological Manifolds John Lee, 2010-12-25 This book is an introduction to manifolds at the beginning graduate level It contains the essential topological ideas that are needed for the further study of manifolds particularly in the context of differential geometry algebraic topology and related fields Its guiding philosophy is to develop these ideas rigorously but economically with minimal prerequisites and plenty of geometric intuition Although this second edition has the same basic structure as the first edition it has been extensively revised and clarified not a single page has been left untouched The major changes include a new introduction to CW complexes replacing most of the material on simplicial complexes in Chapter 5 expanded treatments of manifolds with boundary local compactness group actions and proper maps and a new section on paracompactness This text is designed to be used for an introductory graduate course on the geometry and topology of

manifolds It should be accessible to any student who has completed a solid undergraduate degree in mathematics The author's book *Introduction to Smooth Manifolds* is meant to act as a sequel to this book *Reviews in Functional Analysis, 1980-86*, 1989 The American Mathematical Monthly, 1925 Includes section Recent publications

An Introduction To Topological Groups Book Review: Unveiling the Magic of Language

In an electronic era where connections and knowledge reign supreme, the enchanting power of language has been apparent than ever. Its capability to stir emotions, provoke thought, and instigate transformation is truly remarkable. This extraordinary book, aptly titled "**An Introduction To Topological Groups**," published by a very acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound impact on our existence. Throughout this critique, we shall delve into the book's central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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