

A tour with Constructive Real Numbers

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Abstract. The aim of this work is to characterize constructive real numbers through a minimal axiomatization. We introduce, discuss and justify 16 constructive axioms. Then we address their expressivity considering the alternative axiomatizations.

1 Overview of the work

Real numbers are classically defined as a complete ordered field, but this is not the case in a constructive logic setting: actually the totality of order is not a constructive property.

This work tries to understand (again) constructive real numbers. Our main contribution is a new system of axioms, synthesized with the aim of being minimal, i.e. of assuming the least number of primitive notions and properties. Such a system is consistent with respect to reference models we have in mind — (equivalence classes of) Cauchy sequences [TvD88] and co-inductive streams of digits [CDG00] — and will be compared to other proposals in the literature [Br99, GPWZ00]. The expressive power of the axioms will be addressed in order to guarantee that a sufficient part of the constructive analysis can be derived from them.

We define constructive real numbers through sixteen axioms organized in four groups: arithmetic operations, ordering, Archimedes' postulate and completeness. Our axiomatization uses only three basic concepts: addition (+), multiplication ($\times$) and strict order (<).

In most of the constructive approaches to analysis [Be97, Be85, Wei00] real numbers are defined as a quotient of a set of representations (e.g. equivalence classes of Cauchy sequences, digit expansions, etc.). It follows that also in an axiomatic approach it is necessary to see the reals as a set provided with an equivalence relation. In our proposal, this equivalence relation ($\sim$) is not a primitive notion, but it is derived together with its fundamental properties through the strict order relation. We define the equivalence by $(x \sim y) \triangleq \neg((x < y) \vee (y < x))$; the fact that the equivalence relation is preserved by the arithmetic operations follows from the following axioms, which reverse the usual perspective:

$$\begin{aligned}(x + z < y + z) &\rightarrow (x < y) \\(x \times z < y \times z) &\rightarrow (x < y) \vee ((y < x) \wedge (z < 0))\end{aligned}$$

Constructive Real Numbers Constructive

**Qing Ding, Yixuan Wang, Jianfei
Luo, Hongbo Li**



Constructive Real Numbers Constructive:

Constructive Real Numbers and Constructive Function Spaces Nikolai Aleksandrovich Shanin, 1968 This book is devoted to certain problems of constructive mathematical analysis. The basic sections are Chapters II and III which are devoted to the foundations of the theory of constructive function spaces. Information from the theory of constructive real numbers needed in these chapters is presented in the first chapter. The first chapter also contains other material in it: the logicomathematical symbolism which we shall use is described and some problems of constructive mathematical logic are considered.

Mathematical Logic and Its Applications Dimiter G. Skordev, 2012-12-06 The Summer School and Conference on Mathematical Logic and its Applications September 24 October 4 1986 Druzhba Bulgaria was honourably dedicated to the 80th anniversary of Kurt Godel 1906 1978 one of the greatest scientists of this and not only of this century. The main topics of the Meeting were Logic and the Foundation of Mathematics Logic and Computer Science Logic Philosophy and the Study of Language Kurt Godel's life and deed. The scientific program comprised 5 kinds of activities: namely a) a Godel Session with 3 invited lecturers b) a Summer School with 17 invited lecturers c) a Conference with 13 contributed talks d) Seminar talks one invited and 12 with no preliminary selection e) three discussions. The present volume reflects an essential part of this program: namely 14 of the invited lectures and all of the contributed talks. Not presented in the volume remain six of the invited lecturers who did not submit texts: Yu Ershov The Language of expressions and its Semantics S Goncharov Mathematical Foundations of Semantic Programming Y Moschovakis Foundations of the Theory of Algorithms N Nagornyj Is Realizability of Propositional Formulae a Gödelian Property N Shanin Some Approaches to Finitization of Mathematical Analysis V Uspensky Algorithms and Randomness joint with A N.

Logic, Methodology, and Philosophy of Science IX Dag Prawitz, Brian Skyrms, Dag Westerståhl, 1994 This volume is the product of the Proceedings of the 9th International Congress of Logic Methodology and Philosophy of Science and contains the text of most of the invited lectures. Divided into 15 sections the book covers a wide range of different issues. The reader is given the opportunity to learn about the latest thinking in relevant areas other than those in which they themselves may normally specialise.

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Limit Theorems and Applications of Set-Valued and Fuzzy Set-Valued Random Variables Shoumei Li, Y. Ogura, V. Kreinovich, 2013-04-17 After the pioneering works by Robbins 1944 1945 and Choquet 1955 the notation of a set valued random variable called a random closed set in literatures was systematically introduced by Kendall 1974 and Matheron 1975. It is well known that the theory of set valued random variables is a natural extension of that of general real

valued random variables or random vectors However owing to the topological structure of the space of closed sets and special features of set theoretic operations of Beer 27 set valued random variables have many special properties This gives new meanings for the classical probability theory As a result of the development in this area in the past more than 30 years the theory of set valued random variables with many applications has become one of new and active branches in probability theory In practice also we are often faced with random experiments whose outcomes are not numbers but are expressed in inexact linguistic terms

Nine Papers on Logic and Group Theory, 1967-12-31 Five Papers on Logic and Foundations G. S. Ceitin, 1971-12-31 *The History of Continua* Stewart Shapiro, Geoffrey Hellman, 2021 Mathematical and philosophical thought about continuity has changed considerably over the ages from Aristotle's insistence that a continuum is a unified whole to the dominant account today that a continuum is composed of infinitely many points This book explores the key ideas and debates concerning continuity over more than 2500 years

Mathematics Of Harmony: From Euclid To Contemporary Mathematics And Computer Science Alexey Stakhov, 2009-09-11 Assisted by Scott Olsen Central Florida Community College USA This volume is a result of the author's four decades of research in the field of Fibonacci numbers and the Golden Section and their applications It provides a broad introduction to the fascinating and beautiful subject of the Mathematics of Harmony a new interdisciplinary direction of modern science This direction has its origins in The Elements of Euclid and has many unexpected applications in contemporary mathematics a new approach to a history of mathematics the generalized Fibonacci numbers and the generalized golden proportions the golden algebraic equations the generalized Binet formulas Fibonacci and golden matrices theoretical physics new hyperbolic models of Nature and computer science algorithmic measurement theory number systems with irrational radices Fibonacci computers ternary mirror symmetrical arithmetic a new theory of coding and cryptography based on the Fibonacci and golden matrices The book is intended for a wide audience including mathematics teachers of high schools students of colleges and universities and scientists in the field of mathematics theoretical physics and computer science The book may be used as an advanced textbook by graduate students and even ambitious undergraduates in mathematics and computer science

Numeral Systems With Irrational Bases For Mission-critical Applications Alexey Stakhov, 2017-10-17 This volume is the result of the author's many years of research in this field These results were presented in the author's two books Introduction to the Algorithmic Measurement Theory Moscow Soviet Radio 1977 and Codes of the Golden Proportion Moscow Radio and Communications 1984 which had not been translated into English and are therefore not known to English speaking audience This volume sets forth new informational and arithmetical fundamentals of computer and measurement systems based on Fibonacci p codes and codes of the golden p proportions and also on Bergman's system and golden ternary mirror symmetrical arithmetic The book presents some new historical hypotheses concerning the origin of the Egyptian calendar and the Babylonian numeral system with base 60 dodecahedral hypothesis as well as about the origin of the Mayan's calendar and their numeral system with base 20

icosahedral hypothesis The book is intended for the college and university level The book will also be of interest to all researchers who use the golden ratio and Fibonacci numbers in their subject areas and to all readers who are interested to the history of mathematics Types for Proofs and Programs Thierry Coquand, Peter Dybjer, Bengt Nordström, Jan Smith, 2003-07-31 This book constitutes the thoroughly refereed post workshop proceedings of the Third International Workshop TYPES 99 organized by the ESPRIT Working Group 21900 in L keberg Sweden in June 1999 The 11 revised full papers presented in the volume were carefully reviewed and selected during two rounds of refereeing All current issues on type theory and type systems and their applications to programming and proof theory are addressed The Continuous, the Discrete and the Infinitesimal in Philosophy and Mathematics John L. Bell, 2019-09-09 This book explores and articulates the concepts of the continuous and the infinitesimal from two points of view the philosophical and the mathematical The first section covers the history of these ideas in philosophy Chapter one entitled The continuous and the discrete in Ancient Greece the Orient and the European Middle Ages reviews the work of Plato Aristotle Epicurus and other Ancient Greeks the elements of early Chinese Indian and Islamic thought and early Europeans including Henry of Harclay Nicholas of Autrecourt Duns Scotus William of Ockham Thomas Bradwardine and Nicolas Oreme The second chapter of the book covers European thinkers of the sixteenth and seventeenth centuries Galileo Newton Leibniz Descartes Arnauld Fermat and more Chapter three The age of continuity discusses eighteenth century mathematicians including Euler and Carnot and philosophers among them Hume Kant and Hegel Examining the nineteenth and early twentieth centuries the fourth chapter describes the reduction of the continuous to the discrete citing the contributions of Bolzano Cauchy and Reimann Part one of the book concludes with a chapter on divergent conceptions of the continuum with the work of nineteenth and early twentieth century philosophers and mathematicians including Veronese Poincar Brouwer and Weyl Part two of this book covers contemporary mathematics discussing topology and manifolds categories and functors Grothendieck topologies sheaves and elementary topoi Among the theories presented in detail are non standard analysis constructive and intuitionist analysis and smooth infinitesimal analysis synthetic differential geometry No other book so thoroughly covers the history and development of the concepts of the continuous and the infinitesimal *Logic Colloquium '78, Proceedings of the colloquium held in Mons* Lev D. Beklemishev, 2000-04-01 Logic Colloquium 78 Proceedings of the colloquium held in Mons **Gödel '96** Petr Hájek, 2017-03-02 The proceedings of the conference Logical Foundations of Mathematics Computer Science and Physics Kurt Gödel's Legacy held in Brno Czech Republic on the 90th anniversary of Gödel's birth The papers in this volume cover the wide range of topics Gödel's work touched and affirm its continuing importance Information, Randomness & Incompleteness Gregory J. Chaitin, 1990-01-01 This book contains in easily accessible form all the main ideas of the creator and principal architect of algorithmic information theory This expanded second edition has added thirteen abstracts a 1988 Scientific American Article a transcript of a EUROPALIA 89 lecture an essay on biology and an extensive bibliography Its new

larger format makes it easier to read Chaitin's ideas are a fundamental extension of those of Godel and Turing and have exploded some basic assumptions of mathematics and thrown new light on the scientific method epistemology probability theory and of course computer science and information theory

Exogenous Factors in Colonic Carcinogenesis W. Scheppach, M. Scheurlen, 2003-01-31 This book is the proceedings of Falk Symposium 128 held in Würzburg Germany on May 23 2002 and dedicated to the important issue of colonic carcinogenesis and its underlying genetic and environmental factors Colorectal cancer is one of the leading causes of cancer related death in industrialized countries It has been recognized to be the consequence of a dynamic process leading from hyperproliferative epithelium through different classes of adenomas to invasive carcinoma This adenoma carcinoma sequence has been characterized on a molecular basis Modern molecular biology has also helped to clarify the clustering of colorectal cancer within families a phenomenon that has been known to clinicians for a long time Thus the pathogenesis of the two distinct familial colon cancer syndromes FAP familial adenomatous polyposis and HNPCC hereditary non polyposis colorectal cancer is increasingly being understood Thereby an identification of affected people has become possible before the disease has manifested There is also convincing evidence that the pathogenesis of sporadic colonic cancer is modulated by environmental mainly nutritional factors Carcinogens seem to be far less important than the components of the normal human diet It is likely that the interplay between protective and noxious dietary compounds determines the progression of the adenoma carcinoma sequence Additionally a broad spectrum of drugs has been shown to affect colonic tumorigenesis which provides the rationale for chemoprevention strategies These issues set the scene for discussions on how genetic and environmental factors may interact in the pathogenesis of colonic cancer contributing fresh ideas to the prevention of this most prevalent malignancy in the industrialized world

Proceedings of the 2025 9th International Seminar on Education, Management and Social Sciences (ISEMSS 2025) Qing Ding, Yixuan Wang, Jianfei Luo, Hongbo Li, 2025-10-12 This is an open access book 2025 9th International Seminar on Education Management and Social Sciences ISEMSS 2025 aims to bring together scholars researchers practitioners and policymakers from across the globe to engage in insightful discussions and collaborations on pressing issues in the realms of education management and social sciences As we navigate an increasingly complex and interconnected world this conference offers a vital platform for sharing innovative ideas and best practices that can drive advancements in these critical fields

Nine Papers on Logic and Quantum Electrodynamics V. K. Detlovs, 1963-12-31 Types for Proofs and Programs Paul Callaghan, Zhaohui Luo, James McKinna, Robert Pollack, 2002-02-20 This book constitutes the thoroughly refereed post proceedings of the International Workshop of the TYPES Working Group TYPES 2000 held in Durham UK in December 2000 The 15 revised full papers presented were carefully reviewed and selected during two rounds of refereeing and revision All current issues on type theory and type systems and their applications to programming systems design and proof theory are addressed

Bertrand Russell Memorial Volume George W Roberts, 2013-12-19 This is Volume XXII of twenty two in a

collection on 20th Century Philosophy Originally published in 1979 this volume attempts to assess some of the achievements of Bertrand Russell in philosophy logic and mathematics ethics and politics

Constructive Real Numbers Constructive Book Review: Unveiling the Magic of Language

In a digital era where connections and knowledge reign supreme, the enchanting power of language has become much more apparent than ever. Its ability to stir emotions, provoke thought, and instigate transformation is truly remarkable. This extraordinary book, aptly titled "**Constructive Real Numbers Constructive**," compiled by a highly 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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