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 understaand (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 [Bri99, GPW200]. 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 [Bis67, Bee85, 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:

$$(x + z < y + z) \to (x < y)$$
$$(x \times z < y \times z) \to (x < y) \vee ((y < x) \wedge (z < 0))$$

Constructive Real Numbers Constructive

John L. Bell

Constructive Real Numbers Constructive:

Constructive Real Numbers and Constructive Function Spaces Nikolaĭ Aleksandrovich Shanin,1968 This book is devoted to certain problems of constructive mathematical analysis l 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 **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 *Logic, Methodology and Philosophy of Science IX* D. Prawitz,B. Skyrms,D. Westerståhl,1995-01-10 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 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 cf 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 *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 *Encyclopaedia of Mathematics* M. Hazewinkel,2013-12-01 **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 **Five Papers on Logic and Foundations** G. S. Ceitin,1971-12-31 *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 Nine Papers on Logic and Group Theory ,1967-12-31 **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 G del s Legacy held in Brno Czech Republic on the 90th anniversary of G del s birth The papers in this volume cover the wide range of topics G del s work touched and affirm its continuing importance **Encyclopaedia of Mathematics** Michiel Hazewinkel,2013-12-01 This ENCYCLOPAEDIA OF MATHEMATICS aims to be a reference work for all parts of mathematics It is a translation with updates and editorial comments of the Soviet Mathematical En cyclopaedia published by Soviet Encyclopaedia Publishing House in five volumes in 1977 1985 The annotated translation consists of ten volumes including a special index volume There are three kinds of articles in this ENCYCLOPAEDIA First of all there are survey type articles dealing with the various main directions in mathematics where a rather fine subdivision has been used The main requirement for these articles has been that they should give a reasonably complete up to date account of the current state of affairs in these areas and that they should be maximally accessible On the whole these articles should be understandable to mathe matics students in their first specialization years to graduates from other mathematical areas and depending on the specific subject to specialists in other domains of science engineers and teachers of mathematics These articles treat their material at a fairly general level and aim to give an idea of the kind of problems techniques and concepts involved in the area in question They also contain background and motivation rather than precise statements of precise theorems with detailed definitions and technical details on how to carry out proofs and constructions The second kind of article of medium length contains more detailed concrete problems results and techniques **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 G del and Turning 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 W rzburg Germany on May 2 3 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

Handbook of the History and Philosophy of Mathematical Practice Bharath Sriraman,2024-04-26 The purpose of this unique handbook is to examine the transformation of the philosophy of mathematics from its origins in the history of mathematical practice to the present It aims to synthesize what is known and what has unfolded so far as well as to explore

directions in which the study of the philosophy of mathematics as evident in increasingly diverse mathematical practices is headed Each section offers insights into the origins debates methodologies and newer perspectives that characterize the discipline today Contributions are written by scholars from mathematics history and philosophy as well as other disciplines that have contributed to the richness of perspectives abundant in the study of philosophy today who describe various mathematical practices throughout different time periods and contrast them with the development of philosophy Editorial Advisory Board Andrew Aberdein Florida Institute ofTechnology USA Jody Azzouni Tufts University USA Ot vio Bueno University of Miami USA William Byers Concordia University Canada Carlo Cellucci Sapienza University of Rome Italy Chandler Davis University of Toronto Canada 1926 2022 Paul Ernest University of Exeter UK Michele Friend George Washington University USA Reuben Hersh University of New Mexico USA 1927 2020 Kyeong Hwa Lee Seoul National University South Korea Yuri Manin Max Planck Institute for Mathematics Germany 1937 2023 Athanase Papadopoulos University of Strasbourg France Ulf Persson Chalmers University of Technology Sweden John Stillwell University of San Francisco USA David Tall University of Warwick UK 1941 2024 This book with its exciting depth and breadth illuminates us about the history practice and the very language of our subject about the role of abstraction ofproof and manners of proof about the interplay of fundamental intuitions about algebraic thought in contrast to geometric thought The richness of mathematics and the philosophy encompassing it is splendidly exhibited over the wide range of time these volumes cover from deep platonic and neoplatonic influences to the most current experimental approaches Enriched as well with vivid biographies and brilliant personal essays written by and about people who play an important role in our tradition this extraordinary collection of essays is fittingly dedicated to the memory of Chandler Davis Reuben Hersh and Yuri Manin Barry Mazur Gerhard Gade University Professor Harvard University This encyclopedic Handbook will be a treat for all those interested in the history and philosophy of mathematics Whether one is interested in individuals from Pythagoras through Newton and Leibniz to Grothendieck fields geometry algebra number theory logic probability analysis viewpoints from Platonism to Intuitionism or methods proof experiment computer assistance the reader will find a multitude of chapters that inform and fascinate John Stillwell Emeritus Professor of Mathematics University of San Francisco Recipient of the 2005 Chauvenet Prize Dedicating a volume to the memory of three mathematicians Chandler Davis Reuben Hersh and Yuri Manin who went out of their way to show to a broader audience that mathematics is more than what they might think is an excellent initiative Gathering authors coming from many different backgrounds but who are very strict about the essays they write was successfully achieved by the editor in chief The result a great source of potential inspiration Jean Pierre Bourguignon Nicolaas Kuiper Honorary Professor at the Institut des Hautes tudes Scientifiques **Nine Papers on Logic and Quantum Electrodynamics** V. K. Detlovs,1963-12-31

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