

On Some Types of Functions in Nonstandard Analysis

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Abstract:

In this paper, by using some nonstandard concepts given by Robinson and axiomatized by Nelson we study the behavior of functions defined on a discrete interval, whose points are of infinitesimal distances. This study leads to introduce and define some new types of functions in nonstandard analysis and we get some nonstandard results for different nonstandard values (infinitesimal, infinitely close, unlimited ...).

Keywords: Nonstandard Analysis, Limited Function, Continuity, ϵ -Continuity, g -Continuity.

1-Introduction:

The following definitions and notations of nonstandard analysis will be needed in this paper, which can be found in (Hamad, 2008; Diener and Diener, 1995; Nelson, 1977; Davis, 1977).

Every set or elements defined in a classical mathematics is called **standard**. A real number x is called **unlimited** if $|x| > r$ for all standard positive real number r , otherwise it is called **limited**. A real number x is called **infinitesimal** if $|x| < r$ for all standard positive real numbers r . A real number x is called **appreciable** in case x is limited not infinitesimal. Two real numbers x and y are said to be **infinitely close** if $x - y$ is infinitesimal and is denoted by $x \approx y$. If x is a real number, then the set of all numbers y which are infinitely close to x is called the **monad** of x , and is denoted by $m(x)$, that is $m(x) = \{y \in R : x \approx y\}$, and $\alpha - m(x) = \{y \in R : \frac{y-x}{\alpha} \approx 0\}$. If x is a real number, then the set of all numbers y such that $x - y$ is limited is called the **galaxy** of x and denoted by $gal(x)$, that is $gal(x) = \{y \in R : y - x \text{ limited}\}$, and $\alpha - gal(x) = \{y \in R : \frac{y-x}{\alpha} \text{ limited}\}$. If x is a limited real number in R^* , then it is infinitely close to a unique standard real number, this unique number is called the **standard part** of x and is denoted by $st(x)$. Any set or formula which does not involve a new predicates "standard, infinitesimal, limited, unlimited....etc" is called **internal**, otherwise is called **external**. A standard real valued function f is continuous at a standard point y if for all x , $x \approx y$ then $f(x) \approx f(y)$. A real valued function f is called ϵ -continuous at y if for all x , $x \approx y$ then $f(x) \approx f(y)$. If $f: X \rightarrow Y$ is an internal function, then we say that f is a galaxy continuous at a point y if for all $x \in m(y)$ then $f(x) \in gal(f(y))$, and is denoted by g -continuous. A standard real valued function is **bounded** or **limited** if there exists a standard real number k such that $|f(x)| \leq k$.

Remark 1.1(Hamad, 2008):

1. From definitions of monad and galaxy, we have: $m(x) \subset gal(x)$, for all $x \in R$.
2. From definitions of continuous and ϵ -continuous, we have for all x , $x \in m(y)$, then $f(x) \in m(f(y))$.

2. Some New Types of Nonstandard Functions

With nonstandard analysis the region of tangible elements is larger than that of standard analysis the problems that deal with unusual elements take its frame space in nonstandard analysis, so the study of the behavior of a function and its properties in nonstandard analysis give us a real phase and precision out comes, which can never be imagined classically.

According to this fact and the use of nonstandard tools, we introduce some new nonstandard types of functions.

Definition 2.1: Let $A \subset R$. A function $f: A \rightarrow R$ is said to be of type:

1. LC on A if $f(x)$ is linear and continuous for all $x \in A$, and denoted by $f \in LC$.
2. LSC on A if $f(x)$ is linear and ϵ -continuous for all $x \in A$, and denoted by $f \in LSC$.
3. LOC on A if $f(x)$ is linear and g -continuous for all $x \in A$, and denoted by $f \in LGC$.
4. SCLLP on A if $f(x)$ is ϵ -continuous and limited at every limited point $x \in A$, and denoted by $f \in SCLLP$.
5. GCLLP on A if $f(x)$ is g -continuous and limited at every limited point $x \in A$, and denoted by $f \in GCLLP$.

Remark 2.2: In a classical mathematics, every linear function from usual metric space in to usual metric space is continuous while in nonstandard analysis, for ϵ -continuous, this fact may not be true in general. For example:

Let $f(x) = \omega x + 1$ Where ω is unlimited real number such that $\omega = \frac{1}{\epsilon}$ for all $\epsilon \approx 0$. Take $x = 2 + \epsilon$ and $y = 2$ its clear that $x \approx y$.

Nonstandard Analysis In Practice

Vladimir Kanovei, Michael Reeken



Nonstandard Analysis In Practice:

Nonstandard Analysis in Practice Francine Diener, Marc Diener, 1995-12-14 This book introduces the graduate mathematician and researcher to the effective use of nonstandard analysis NSA It provides a tutorial introduction to this modern theory of infinitesimals followed by nine examples of applications including complex analysis stochastic differential equations differential geometry topology probability integration and asymptotics It ends with remarks on teaching with infinitesimals

Non-standard Analysis Abraham Robinson, 2016-08-11 Considered by many to be Abraham Robinson's magnum opus this book offers an explanation of the development and applications of non standard analysis by the mathematician who founded the subject Non standard analysis grew out of Robinson's attempt to resolve the contradictions posed by infinitesimals within calculus He introduced this new subject in a seminar at Princeton in 1960 and it remains as controversial today as it was then This paperback reprint of the 1974 revised edition is indispensable reading for anyone interested in non standard analysis It treats in rich detail many areas of application including topology functions of a real variable functions of a complex variable and normed linear spaces together with problems of boundary layer flow of viscous fluids and rederivations of Saint Venant's hypothesis concerning the distribution of stresses in an elastic body

Nonstandard Analysis, Axiomatically Vladimir Kanovei, Michael Reeken, 2013-03-09 In the aftermath of the discoveries in foundations of mathematics there was surprisingly little effect on mathematics as a whole If one looks at standard textbooks in different mathematical disciplines especially those closer to what is referred to as applied mathematics there is little trace of those developments outside of mathematical logic and model theory But it seems fair to say that there is a widespread conviction that the principles embodied in the Zermelo Fraenkel theory with Choice ZFC are a correct description of the set theoretic underpinnings of mathematics In most textbooks of the kind referred to above there is of course no discussion of these matters and set theory is assumed informally although more advanced principles like Choice or sometimes Replacement are often mentioned explicitly This implicitly fixes a point of view of the mathematical universe which is at odds with the results in foundations For example most mathematicians still take it for granted that the real number system is uniquely determined up to isomorphism which is a correct point of view as long as one does not accept to look at unnatural interpretations of the membership relation

Nonstandard Analysis Alain Robert, 2003-01-01 This concise text is based on the axiomatic internal set theory approach Theoretical topics include idealization standardization and transfer real numbers and numerical functions continuity differentiability and integration Applications cover invariant means approximation of functions differential equations more Exercises hints and solutions Mathematics teaching at its best European Journal of Physics 1988 edition

Nonstandard Analysis Martin Andreas V  th, 2006-12-26 This book introduces Robinson's nonstandard analysis an application of model theory in analysis Unlike some texts it does not attempt to teach elementary calculus on the basis of nonstandard analysis but points to some applications in more advanced analysis The

contents proceed from a discussion of the preliminaries to Nonstandard Models Nonstandard Real Analysis Enlargements and Saturated Models Functionals Generalized Limits and Additive Measures and finally Nonstandard Topology and Functional Analysis No background in model theory is required although some familiarity with analysis topology or functional analysis is useful This self contained book can be understood after a basic calculus course Perspectives on Mathematical Practices Bart van Kerkhove, Jean Paul van Bendegem, 2007-06-01 Philosophy of mathematics today has transformed into a very complex network of diverse ideas viewpoints and theories Sometimes the emphasis is on the classical foundational work often connected with the use of formal logical methods sometimes on the sociological dimension of the mathematical research community and the products it produces then again on the education of future mathematicians and the problem of how knowledge is or should be transmitted from one generation to the next The editors of this book felt the urge first of all to bring together the widest variety of authors from these different domains and secondly to show that this diversity does not exclude a sufficient number of common elements to be present In the eyes of the editors this book will be considered a success if it can convince its readers of the following that it is warranted to dream of a realistic and full fledged theory of mathematical practices in the plural If such a theory is possible it would mean that a number of presently existing fierce oppositions between philosophers sociologists educators and other parties involved are in fact illusory **Nonstandard Analysis** Leif O. Arkeryd, Nigel J. Cutland, C. Ward Henson, 1997-04-30 1 More than thirty years after its discovery by Abraham Robinson the ideas and techniques of Nonstandard Analysis NSA are being applied across the whole mathematical spectrum as well as constituting an important field of research in their own right The current methods of NSA now greatly extend Robinson's original work with infinitesimals However while the range of applications is broad certain fundamental themes recur The nonstandard framework allows many informal ideas that could loosely be described as idealisation to be made precise and tractable For example the real line can in this framework be treated simultaneously as both a continuum and a discrete set of points and a similar dual approach can be used to link the notions infinite and finite rough and smooth This has provided some powerful tools for the research mathematician for example Loeb measure spaces in stochastic analysis and its applications and nonstandard hulls in Banach spaces The achievements of NSA can be summarised under the headings i explanation giving fresh insight or new approaches to established theories ii discovery leading to new results in many fields iii invention providing new rich structures that are useful in modelling and representation as well as being of interest in their own right The aim of the present volume is to make the power and range of applicability of NSA more widely known and available to research mathematicians Nonstandard Analysis Karl Kuhlemann, 2024-12-16 Currently nonstandard analysis is barely considered in university teaching The author argues that nonstandard analysis is valuable not only for teaching but also for understanding standard analysis and mathematics itself An axiomatic approach which pays attention to different language levels for example in the distinction between sums of ones and the natural numbers of the

theory leads naturally to a nonstandard theory For motivation historical ideas of Leibniz can be taken up The book contains an elaborated concept that follows this approach and is suitable for example as a basis for a lecture supplementary course The monograph part presents all major approaches to nonstandard analysis and discusses logical model theoretic and set theoretic investigations to reveal possible mathematical reasons that may lead to reservations about nonstandard analysis Also various foundational positions as well as ontological epistemological and application related issues are addressed It turns out that the one sided preference for standard analysis is justified neither from a didactic mathematical nor philosophical point of view Thus the book is especially valuable for students and instructors of analysis who are also interested in the foundations of their subject

Lectures on the Hyperreals Robert Goldblatt, 1998-10-01 An introduction to nonstandard analysis based on a course given by the author It is suitable for beginning graduates or upper undergraduates or for self study by anyone familiar with elementary real analysis It presents nonstandard analysis not just as a theory about infinitely small and large numbers but as a radically different way of viewing many standard mathematical concepts and constructions It is a source of new ideas objects and proofs and a wealth of powerful new principles of reasoning The book begins with the ultrapower construction of hyperreal number systems and proceeds to develop one variable calculus analysis and topology from the nonstandard perspective It then sets out the theory of enlargements of fragments of the mathematical universe providing a foundation for the full scale development of the nonstandard methodology The final chapters apply this to a number of topics including Loeb measure theory and its relation to Lebesgue measure on the real line Highlights include an early introduction of the ideas of internal external and hyperfinite sets and a more axiomatic set theoretic approach to enlargements than is usual

Nonstandard Analysis and Its Applications Nigel Cutland, 1988-09-30 This textbook is an introduction to non standard analysis and to its many applications Non standard analysis NSA is a subject of great research interest both in its own right and as a tool for answering questions in subjects such as functional analysis probability mathematical physics and topology The book arises from a conference held in July 1986 at the University of Hull which was designed to provide both an introduction to the subject through introductory lectures and surveys of the state of research The first part of the book is devoted to the introductory lectures and the second part consists of presentations of applications of NSA to dynamical systems topology automata and orderings on words the non linear Boltzmann equation and integration on non standard hulls of vector lattices One of the book s attractions is that a standard notation is used throughout so the underlying theory is easily applied in a number of different settings Consequently this book will be ideal for graduate students and research mathematicians coming to the subject for the first time and it will provide an attractive and stimulating account of the subject

The Strength of Nonstandard Analysis Imme van den Berg, Vitor Neves, 2007-12-03 Nonstandard Analysis enhances mathematical reasoning by introducing new ways of expression and deduction Distinguishing between standard and nonstandard mathematical objects its inventor the eminent mathematician Abraham Robinson settled

in 1961 the centuries old problem of how to use infinitesimals correctly in analysis Having also worked as an engineer he saw not only that his method greatly simplified mathematically proving and teaching but also served as a powerful tool in modelling analyzing and solving problems in the applied sciences among others by effective rescaling and by infinitesimal discretizations This book reflects the progress made in the forty years since the appearance of Robinson s revolutionary book *Nonstandard Analysis* in the foundations of mathematics and logic number theory statistics and probability in ordinary partial and stochastic differential equations and in education The contributions are clear and essentially self contained

Nonstandard Analysis for the Working Mathematician Peter A. Loeb, Manfred P. H. Wolff, 2015-08-26 Starting with a simple formulation accessible to all mathematicians this second edition is designed to provide a thorough introduction to nonstandard analysis Nonstandard analysis is now a well developed powerful instrument for solving open problems in almost all disciplines of mathematics it is often used as a secret weapon by those who know the technique This book illuminates the subject with some of the most striking applications in analysis topology functional analysis probability and stochastic analysis as well as applications in economics and combinatorial number theory The first chapter is designed to facilitate the beginner in learning this technique by starting with calculus and basic real analysis The second chapter provides the reader with the most important tools of nonstandard analysis the transfer principle Keisler s internal definition principle the spill over principle and saturation The remaining chapters of the book study different fields for applications each begins with a gentle introduction before then exploring solutions to open problems All chapters within this second edition have been reworked and updated with several completely new chapters on compactifications and number theory *Nonstandard Analysis for the Working Mathematician* will be accessible to both experts and non experts and will ultimately provide many new and helpful insights into the enterprise of mathematics

Nonstandard Asymptotic Analysis Imme van den Berg, 2006-11-15 This research monograph considers the subject of asymptotics from a nonstandard view point It is intended both for classical asymptoticists they will discover a new approach to problems very familiar to them and for nonstandard analysts but includes topics of general interest like the remarkable behaviour of Taylor polynomials of elementary functions Noting that within nonstandard analysis small large and domain of validity of asymptotic behaviour have a precise meaning a nonstandard alternative to classical asymptotics is developed Special emphasis is given to applications in numerical approximation by convergent and divergent expansions in the latter case a clear asymptotic answer is given to the problem of optimal approximation which is valid for a large class of functions including many special functions The author s approach is didactical The book opens with a large introductory chapter which can be read without much knowledge of nonstandard analysis Here the main features of the theory are presented via concrete examples with many numerical and graphic illustrations N

An Introduction to Nonstandard Real Analysis Albert E. Hurd, Peter A. Loeb, 1985-10-01 The aim of this book is to make Robinson s discovery and some of the subsequent research available to students with a background in

undergraduate mathematics In its various forms the manuscript was used by the second author in several graduate courses at the University of Illinois at Urbana Champaign The first chapter and parts of the rest of the book can be used in an advanced undergraduate course Research mathematicians who want a quick introduction to nonstandard analysis will also find it useful The main addition of this book to the contributions of previous textbooks on nonstandard analysis 12 37 42 46 is the first chapter which eases the reader into the subject with an elementary model suitable for the calculus and the fourth chapter on measure theory in nonstandard models

Bulletin of the Belgian Mathematical Society, Simon Stevin, 2006 Optimization and Nonstandard Analysis J.E. Rubio, 1994-08-10 This text presents an up to date overview of optimization and control theory including existence theory modelling approximation and numerical methods It also provides a self contained treatment of the theory and practice of non standard analysis and its applications illustrated with problems and research material based on optimization theory A complete set of detailed exercises and a thorough bibliography arranged by topic are included College or university bookstores may order five or more copies at a special student price available upon request Applications of Model Theory to Algebra, Analysis, and Probability W. A. J. Luxemburg, 1969

Nonstandard Analysis, Axiomatically Vladimir Grigor'evich Kanovei, Michael Reeken, 2004-08-11 The book is devoted to nonstandard set theories that serve as foundational basis for nonstandard mathematics Several popular and some less known nonstandard theories are considered including internal set theory IST Hrbacek set theory HST and others The book presents the basic structure of the set universe of these theories and methods to effectively develop applied nonstandard analysis metamathematical properties and interrelations of these nonstandard theories between each other and with ZFC and some variants of ZFC foundational problems of the theories including the problem of external sets and the Power Set problem and methods of their solution The book is oriented towards a reader having some experience in foundations set theory model theory and in nonstandard analysis Topological Methods in Nonlinear Analysis, 2002 Applied Nonstandard Analysis Martin Davis, 2005-07-26 This text assumes no knowledge of mathematical logic Beginning with a nonstandard construction of the real number system it leads students thorough the basic topics of elementary real analysis topological spaces and Hilbert space Includes nonstandard treatments of equicontinuity nonmeasurable sets and the existence of Haar measure 1977 edition

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