

## 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,  $\varepsilon$ -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  $\varepsilon$ -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  $\varepsilon$ -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  $\varepsilon$ -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  $\varepsilon$ -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  $\varepsilon$ -continuous, this fact may not be true in general. For example:

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

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