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NeutroAlgebra for the evaluation of barriers to migrants' access in Primary Health Care in Chile based on PROSPECTOR function

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Abstract. This research is the result of the CIP 2018016 project of the Universidad Central of Chile. The migrant population has beliefs, values and health practices different from Chilean people, for which Chilean citizens are not prepared as a society or health sector. The purpose of this research is to investigate which are the access barriers to health that the international migrant population faces in primary health care in Chile. To accomplish this objective, a group of migrants was surveyed on an evaluation scale between -10 to 10 in various aspects of access to health. A generalization of the well-known PROSPECTOR function was used as aggregator, where the aggregation between the two extreme values is undefined. Except for indefiniteness, this function is a truth membership of an offuninorm or a uninorm in the interval [-1, 1]. We preferred to keep the indeterminacy to take into account totally contradictory opinions. This turns the generalization of the PROSPECTOR function into a NeutroFunction, and this problem into an application of NeutroAlgebra.

Keywords: Access barriers, access to health, international migrant, primary care, PROSPECTOR, uninorm, offuninorm, NeutroFunction, NeutroAlgebr

1. Introduction

The World Health Organization (WHO) states that a health system brings together all the institutions and organizations whose primary objective is to maintain and improve the health of the population. Most health systems are made up of different sectors, public, private, traditional and informal, and must provide good treatments and services that respond to the needs of the population and are fair from a financial point of view, [1].

The Chilean health system is mixed, both in insurance and in the provision of services. This is done through two subsystems, one private and one public. The private sector delivers closed and outpatient health actions of varying complexity, for profit. In the public sector, the provision of services is carried out through the National Health System, which has 29 services distributed throughout the country and must be registered in "Fondo Nacional de Salud" or National Fund of Health (FONASA in Spanish). Health care is provided at different levels of complexity, from primary to tertiary level, the first one is the point of access to the public sector through the Family Health Centers (CESFAM in Spanish), [2].

"Access to health services is the ability to get care when it is needed, [2, 3]. This can be determined by various factors and variables such as the location of health centers and the availability of medical or health providers (geographical or physical barriers), up to health insurance and health care costs, also can be influenced by cultural barriers or language.", [2].

The phenomenon of international migration to Chile had a slow beginning at the dawn of the 90s, from

the neighboring countries, as the decades passed, it took on an unusual force, with international migrants in Chile today reaching 2.7% of the total population, [4]. The migrant population of the South East Metropolitan Health Service (SSMSO in Spanish) corresponds to 1.35%. The commune of Florida represents 39% of that population, which is the largest in the SSMSO and is the one with the highest vulnerability index, [5].

The arrival of migrants to the country may represent an opportunity to improve their health because "Chile has greater control of infectious and nutritional diseases compared to other Latin American countries, which can increase life expectancy" ([6]) as long as they can access the health system.

"The access difficulties of undocumented immigrants are reinforced by two aspects: the breach of ministerial agreements and the personal criteria of the agents", [7]. This means that the migrant population that is not assigned to any health service corresponds to 15.7%, while children under 14 years of age reach 26.6 of this percent, [2]. This means that immigrants are about 7.5 times more likely to have no health insurance than Chileans, which means that immigrants show less need for health than the natives do, which is accompanied at the time of requesting care. They do not attend any assistance and if they attend their health, then their demand is not satisfied ([8]). Low-income people have a lesser chance of accessing health services when they need it ([3]). This is the same as that of the indigenous population in Guatemala ([9]), generating inequality and intersector inequity.

This research aims to evaluating the access barriers to health that the international migrant population faces in primary health care in Chile. To achieve this objective, a group of 28 international migrants of different sexes and nationalities who are cared at the Santa Amalia CESFAM of Florida Commune are surveyed, who belong to the Eastern Metropolitan Health Service. Respondents evaluated different relevant aspects in health care on a numerical scale with a maximum of 10 for approval and a minimum of -10 for disapproval. A generalization of the well-known PROSPECTOR function of the MYCIN medical expert system, is used, [10-12]. This function has proven effectiveness in practice as an aggregator. On the other hand, it is undefined when applied to the two extreme values -1 and 1, where a total contradiction is shown in the evaluation.

This function is a mapping from $[-1,1]^2$ into $[-1,1]$ that is classified as a uninorm in this interval, [13]. A uninorm is an aggregation operator that generalizes the notion of t-norm and t-conorm, where the axioms of commutativity, associativity, monotonicity, and the existence of a neutral element are maintained, [12-14]. Regarding this last axiom, the uninorm contains a neutral element different from 0 and 1. The PROSPECTOR has as a neutral element 0 if it extends to the interval $[-1,1]$ and 0.5 if it is rescaled to the interval $[0,1]$. Except for the indefiniteness, this function is considered the truth membership function of an offuninorm, [15], which are uninorms defined for neutrosophic offsets, [16-19], which are neutrosophic sets with truth values >1 or <0. This theory generalizes the notion of neutrosophic uninorms, [20, 21], which in turn generalize the notion of fuzzy uninorm and of uninorms defined in intuitionistic fuzzy sets, [22-25].

In this paper we prefer to keep undefined the aggregation of the values -1 and 1, because we want to consider any uncertainty or indeterminacy in the evaluation of health care in Chile. This feature of the generalized PROSPECTOR function turns it into a NeutroFunction, and therefore the operations between the elements become operations within a NeutroAlgebra, since it does not satisfy the associativity axiom. A NeutroAlgebra is an algebra which has at least one NeutroOperation or one NeutroAxiom (axiom that is true for some elements, indeterminate for other elements, and false for the other elements), [26-28]. Some neutrosophic approaches to algebra can be read in [29-35].

This paper is divided into the following sections. Section 2 is dedicated to recalling the main concepts of NeutroAlgebra and PROSPECTOR function. Section 3 presents the method that we will use to measure the situation of access to health according to the surveyed migrants, as well as the results obtained. This ends with the conclusions. Appendix A contains a table of a NeutroAlgebra generated by generalizing the PROSPECTOR function[36].

2. Preliminaries

This section contains the main concepts of NeutroAlgebra and PROSPECTOR function.

The algebraic structures were extended by Smarandache (in 2019 and 2020) to NeutroAlgebras and AntiAlgebras [24-26].

Definition 1) [26]: Let X be a given nonempty space (or simply set) included into a universe of discourse U. Let <A> be an item (concept, attribute, idea, proposition, theory, etc.) defined on the set X. Through the process of neutrosophication, we split the set X into three regions [two opposite ones <A> and <antiA>, and one neutral (indeterminate) <neutroA> between them], regions which may or may not be disjoint – depending on the application, but they are exhaustive (their union equals the whole space
A *NeutroAlgebra* is an algebra which has at least one *NeutroOperation* or one *NeutroAxiom* (axiom that is true for some elements, indeterminate for other elements, and false for other elements).

The NeutroAlgebra is a generalization of *Partial Algebra*, which is an algebra that has at least one *Partial Operation*, while all its Axioms are totally true (classical axioms).

Definition 2) [26].: A function f: X → Y is called a *Partial Function* if it is well-defined for some elements in X, and undefined for all the other elements in X. Therefore, there exist some elements $a \in X$ such that $f(a) \in Y$ (well-defined), and for all other element $b \in X$ we have $f(b)$ is undefined.

Definition 3 [27]: A function f: X → Y is called a *NeutroFunction* if it has elements in X for which the function is well-defined {degree of truth (T)}, elements in X for which the function is indeterminate {degree of indeterminacy (I)}, and elements in X for which the function is outer-defined {degree of falsehood (F)}, where $T, I, F \in [0,1]$, with $(T, I, F) \neq (1,0,0)$ that represents the (Total) Function, and $(T, I, F) \neq (0,0,1)$ that represents the AntiFunction.

Classification of Functions

i) (Classical) Function, which is a function well-defined for all the elements in its domain of definition.

ii) NeutroFunction, which is a function partially well-defined, partially indeterminate, and partially outer-defined on its domain of definition.

iii) AntiFunction, which is a function outer-defined for all the elements in its domain of definition.

Definition 4: A (classical) *Algebraic Structure* (or Algebra) is a nonempty set A endowed with some (totally well-defined) operations (functions) on A, and satisfying some (classical) axioms (totally true) - according to the Universal Algebra.) [26-27-, 28, 29].

Definition 5 ([26, 27]): A (classical) *Partial Algebra* is an algebra defined on a nonempty set PA that is endowed with some partial operations (or partial functions: partially well-defined, and partially undefined). While the axioms (laws) defined on a Partial Algebra are all totally (100%) true.

Definition 6 ([26, 27]): A *NeutroAxiom* (or *Neutrosophic Axiom*) defined on a nonempty set is an axiom that is true for some set of elements {degree of truth (T)}, indeterminate for other set of elements {degree of indeterminacy (I)}, or false for the other set of elements {degree of falsehood (F)}, where $T, I, F \in [0,1]$, with $(T, I, F) \neq (1,0,0)$ that represents the (classical) Axiom, and $(T, I, F) \neq (0,0,1)$ that represents the AntiAxiom.

Classification of Algebras

i) A (classical) *Algebra* is a nonempty set CA that is endowed with total operations (or total functions, i.e. true for all set elements) and (classical) Axioms (also true for all set elements).

ii) A *NeutroAlgebra* (or *NeutroAlgebraic Structure*) is a nonempty set NA that is endowed with: at least one *NeutroOperation* (or *NeutroFunction*), or one *NeutroAxiom* that is referred to the set (partial-, neutro, or total-) operations.

iii) An *AntiAlgebra* (or *AntiAlgebraic Structure*) is a nonempty set AA that is endowed with at least one *AntiOperation* (or *AntiFunction*) or at least one *AntiAxiom*.

Additionally, the PROSPECTOR function is defined in the MYCIN expert system in the following way; it is a mapping from $[-1,1]^2$ into $[-1,1]$ with formula, [10-12]:

$$P(x,y) = \frac{x+y}{1+xy} \qquad (1)$$

This function is a uninorm with neutral element 0, thus it fulfils commutativity, associativity, and monotonicity. $P(-1,1)$ and $P(1,-1)$ are undefined.

3. Results

This section is dedicated to expose the method we will use and the achieved results.
First of all, for convenience we extend $P(x,y)$ to $\bar{P}(x,y)$ such that:
$\bar{P}(x,y) = P(x,y)$ for all $(x,y) \in [-1,1]^2 \setminus \{(-1,1),(1,-1)\}$,
$\bar{P}(-1,1) = \bar{P}(1,-1) = undefined$,
$\bar{P}(undefined, undefined) = undefined$.

$$\bar{P}(undefined, x) = \bar{P}(x, undefined) = \begin{cases} \text{undefined, if x} > 0 \\ \text{x, if x} \leq 0 \end{cases}.$$

Definition 7: Let S be a finite set defined as $S = \{(x,y): x,y \in \{k, undefined\},\ k \in \mathbb{Z} \cap [-10,10]\}$.

The operator $\odot$ is defined for every $(x,y) \in S$, such that:

1. If $\bar{P}(x,y)$ is not undefined, then $\odot\, y = \frac{round(\bar{P}(x,y)*10)}{10}$, where *round* is the function that output the interger nearest to the argument.
2. If $\bar{P}(x,y)$ is undefined then $x \odot y = undefined$.

   Then $\odot$ is a finite NeutroAlgebra. This is because $\odot$ is commutative and associative for the subset of elements of S without any undefined component, but it is not associative otherwise.

E.g., if $a = -0.9$, $b = 0.8$, $c = undefined$, then $a \odot (b \odot c) = a$ and $(a \odot b) \odot c = -0.4 \neq a$, ther fore associativity is a NeutroAxiom.

We used the function *round* for guarantying $\odot$ is an inner operator.

This research was approved by the SSMSO ethics committee on November 8, 2018, the interviews were conducted during January 2019 after explanation of the research and signing of the informed consent. To evaluate the access barriers, those defined by the Government of Chile (2011) were used, [4], which correspond to four variables.

Variables that have been used in different researches on access to health in Latin America and Chile ([37]) are the following:

1. Geographical and transport access barriers,
2. Cultural access barriers,
3. Financial access barriers,
4. Legal access barrier.

The proposed method is the following:

1. For each previous aspect, the opinion of 28 selected migrants is collected. They are asked to rate each aspect on a scale of 0 to 10 if they have a favorable or neutral opinion about access to public health from the point of view of the access that is measured. On the other hand, they are asked to evaluate on a scale of -10 to -1 if they have an unfavorable opinion.

Let us denote by v_{ij}, $(i = 1,2,\dots,28;\ j = 1,2,3,4)$ the evaluation of the ith migrant on the jth a pect.

2. The value obtained in the evaluation of each aspect for each migrant is rescaled to the interval $[-1,1]$, dividing by 10. That is, $nv_{ij} = \frac{v_{ij}}{10}$ is obtained.

3. It is decided on two different situations:

3.1. If less than 33.333% of the respondents show contradictory results for each fixed j, that is, if there

are 4 pairs or less of values $(-1,1)$ or $(1,-1)$, these values are eliminated for aggregating.

3.2. Otherwise the jth aspect is evaluated as "undefined" and it should be reviewed in more detail why there is such a contradiction.

4. When we have the case 3.1. the aggregation of the remaining values is calculated by using $\odot$.

The results obtained from applying this method were as follows:

Table 1 summarizes the assessments provided by the interviewed on the four barriers.

Assessment	Geographical and transport access barriers	Cultural access barriers	Financial access barriers	Legal access barrier
-10	0	0	0	1
-9	0	0	0	2
-8	0	0	0	0
-7	0	0	0	0
-6	0	0	0	4
-5	0	0	3	7
-4	0	0	4	6
-3	0	0	0	0
-2	0	0	0	0
-1	0	0	0	0
0	0	0	0	0
1	0	0	2	3
2	0	0	5	0
3	0	1	1	2
4	2	1	3	3
5	4	2	9	0
6	0	5	0	0
7	1	7	0	0
8	16	8	1	0
9	3	3	0	0
10	2	1	0	0

Table 1: Number of migrants who evaluate the four barriers in the scale -10-10.

Aggregating the data of Table 1 using $\odot$ we have the following results based on Tables 2 and 3 in Appendix A:

1. $\odot_{i=1}^{28} nv_{i1} = 1$, which means there is sufficient evidence that "Geographical and transport access barriers" is good.

2. $\odot_{i=1}^{28} nv_{i2} = 1$, which means there is sufficient evidence that "Cultural access barriers" is good.
3. $\odot_{i=1}^{28} nv_{i3} = -1$, which means there is sufficient evidence that "Financial access barriers" is bad.
4. $\odot_{i=1}^{28} nv_{i4} = -1$, which means there is sufficient evidence that "Legal access barrier" is bad.

For quantitative purpose we calculate the mean of the evaluations for every aspect, which are as follows:

1. $\overline{nv}_{i1} = 7.5$,
2. $\overline{nv}_{i2} = 7.0357$,
3. $\overline{nv}_{i3} = 1.75$,
4. $\overline{nv}_{i4} = -3.4615$.

Conclusion

This paper is dedicated to evaluate the barriers to migrants' access in primary health care in a centre in Chile. We evaluated four types of barriers, which are "Geographical and transport access barriers", "Cultural access barriers", "Financial access barriers", and "Legal access barrier". Twenty-eight migrants of a Family Health Center provided their opinions in a scale from -10 to 10. This is not a statistical study, thus we defined an operator based on the PROSPECTOR function for determining if there is sufficient evidence to evaluate every aspect. We concluded that "Geographical and transport access barriers" and "Cultural access barriers" are good, whereas "Financial access barriers" and "Legal access barrier" are bad. We provided the Cayley table of $\odot$, which is not associative when we included the undefined value and it generates a NeutroAlgebra. We preferred to maintain the undefinition of the PROSPECTOR function because this indicates there is contradiction.

Appendix A

The following tables summarize the Cayley table of the NeutroAlgebra generated by $\odot$.

$x \odot y$	**-1**	**-0.9**	**-0.8**	**-0.7**	**-0.6**	**-0.5**	**-0.4**	**-0.3**	**-0.2**	**-0.1**	**0**
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-0.9	-1	-1	-1	-1	-1	-1	-1	-0.9	-0.9	-0.9	-0.9
-0.8	-1	-1	-1	-1	-0.9	-0.9	-0.9	-0.9	-0.9	-0.8	-0.8
-0.7	-1	-1	-1	-0.9	-0.9	-0.9	-0.9	-0.8	-0.8	-0.7	-0.7
-0.6	-1	-1	-0.9	-0.9	-0.9	-0.8	-0.8	-0.8	-0.7	-0.7	-0.6
-0.5	-1	-1	-0.9	-0.9	-0.8	-0.8	-0.8	-0.7	-0.6	-0.6	-0.5
-0.4	-1	-1	-0.9	-0.9	-0.8	-0.8	-0.7	-0.6	-0.6	-0.5	-0.4
-0.3	-1	-0.9	-0.9	-0.8	-0.8	-0.7	-0.6	-0.6	-0.5	-0.4	-0.3
-0.2	-1	-0.9	-0.9	-0.8	-0.7	-0.6	-0.6	-0.5	-0.4	-0.3	-0.2
-0.1	-1	-0.9	-0.8	-0.7	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1
un-def.	-1	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0
0	-1	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0
0.1	-1	-0.9	-0.8	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0	0.1
0.2	-1	-0.9	-0.7	-0.6	-0.5	-0.3	-0.2	-0.1	0	0.1	0.2
0.3	-1	-0.8	-0.7	-0.5	-0.4	-0.2	-0.1	0	0.1	0.2	0.3
0.4	-1	-0.8	-0.6	-0.4	-0.3	-0.1	0	0.1	0.2	0.3	0.4
0.5	-1	-0.7	-0.5	-0.3	-0.1	0	0.1	0.2	0.3	0.4	0.5
0.6	-1	-0.7	-0.4	-0.2	0	0.1	0.3	0.4	0.5	0.5	0.6
0.7	-1	-0.5	-0.2	0	0.2	0.3	0.4	0.5	0.6	0.6	0.7
0.8	-1	-0.4	0	0.2	0.4	0.5	0.6	0.7	0.7	0.8	0.8
0.9	-1	0	0.4	0.5	0.7	0.7	0.8	0.8	0.9	0.9	0.9
1	undef.	1	1	1	1	1	1	1	1	1	1

Table 2: Cayley table of $\odot$

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$x \odot y$	un-def.	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	undef.
-0.9	-0.9	-0.9	-0.9	-0.8	-0.8	-0.7	-0.7	-0.5	-0.4	0	1
-0.8	-0.8	-0.8	-0.7	-0.7	-0.6	-0.5	-0.4	-0.2	0	0.4	1
-0.7	-0.7	-0.6	-0.6	-0.5	-0.4	-0.3	-0.2	0	0.2	0.5	1
-0.6	-0.6	-0.5	-0.5	-0.4	-0.3	-0.1	0	0.2	0.4	0.7	1
-0.5	-0.5	-0.4	-0.3	-0.2	-0.1	0	0.1	0.3	0.5	0.7	1
-0.4	-0.4	-0.3	-0.2	-0.1	0	0.1	0.3	0.4	0.6	0.8	1
-0.3	-0.3	-0.2	-0.1	0	0.1	0.2	0.4	0.5	0.7	0.8	1
-0.2	-0.2	-0.1	0	0.1	0.2	0.3	0.5	0.6	0.7	0.9	1
-0.1	-0.1	0	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1
un-def.	undef.	undef.	undef.	undef.	undef.	undef.	undef.	undef.	undef.	undef.	undef.
0	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0.1	undef.	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1
0.2	undef.	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.9	0.9	1
0.3	undef.	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.9	0.9	1
0.4	undef.	0.5	0.6	0.6	0.7	0.8	0.8	0.9	0.9	1	1
0.5	undef.	0.6	0.6	0.7	0.8	0.8	0.8	0.9	0.9	1	1
0.6	undef.	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1	1
0.7	undef.	0.7	0.8	0.8	0.9	0.9	0.9	0.9	1	1	1
0.8	undef.	0.8	0.9	0.9	0.9	0.9	0.9	1	1	1	1
0.9	undef.	0.9	0.9	0.9	1	1	1	1	1	1	1
1	undef.	1	1	1	1	1	1	1	1	1	1

Table 3: Cayley table of $\odot$ (Continuation).

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