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MULTIPOLAR-VALUED FUZZY SETS TO DEAL WITH THE COGNITIVE AMBIGUITIES

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Abstract. *Our brains process in real time, a large amount of demands. First and automatically, they deal with ones concerning to metabolic maintenance for obvious reasons, i.e., survival, but strictly related with the answers supplied by the interaction among the perceived sensory stimuli according to the interaction with the world in which they are contextually inserted, and which will establish a proper behavior to face each specific challenge. If there is any kind of severe pathology, our five senses perceive similarly, the external stimuli, differently only in the answers supplied by a mental process of inference, intrinsic of each person who has its own inference judgments. Regarding this ascertainment, it becomes easy to perceive that our brains deal with a multi-set of Information that can vary instantaneously and randomly, upon a time, and so, adjust the behavior of a person to an environment. The reasoning results do not take into account only the Boolean analysis or the principle of YinYang, because a global answer to adjust the behavior in order to face some imminent challenges, passes obligatorily by a multipolar process of the interaction among the intervenient components that are related with such events and that can disturb some momentary equilibrium or keep a perturbation along a certain time. It also becomes clear that it is not a trivial process, which can be handled by a formal logic, due to the fact that the variables involved can be considered, as much as possible randomly, even why they depend on the set of the environment stimuli, that can change upon a time. Nothing can be assumed as totally true or false. The research has pointed out that the concepts of fuzzy sets could be applied successfully, mainly because they deal with ambiguities that can create similar processes as executed by our brains. It must be considered yet the possibility to introduce a new concept of a Matrix of Interdependence among the membership of any kind of Information perceived along certain time, from which will be possible to evaluate how it impacts the equilibrium, and in a future development, introduce the concept of "speed of transience" among our sensory attributes, which will provide a dynamic feature to the process and also to adjust cognitive ambiguities, to supply more reliable data to a computational tool of a reasoning and decision-making system. After a deeper study of several available techniques, these authors present and propose a Multipolar-Valued Fuzzy Set – MVFS, which represents an extension of a Bipolar-Valued Fuzzy Set – BVFS, which on the other hand had integrated the Interval-Valued Fuzzy Set – IVFS and Rough Set – RS, being this, the major finding and contribution of this work of research.*

Keywords: Fuzzy sets, Fuzzy systems and their applications, Knowledge discovery

1. **Introduction.** Since ancient Greece, Aristotle (384-322 B.C.) in "Prior Analytics", clearly stated that everything based on a syllogism, is some kind of identity, despite that about such identification can disturb an environment, depending, obviously, on the context that it is inserted.

Even syllogisms that result from contrary terms or not applicable to the same individual are reducible to a syllogism figure, in which there is a minimum identity [1]; otherwise the context remains ambiguous and consequently misunderstood.

Taking into account such philosophical basis, it can be easily inferred about a natural existence of an intrinsic cognitive faculty assigned only to Human Beings, that create relationships and maps its respective universes, finites, linked to the tangency or intersection within the world that surrounds them, independently of their physical conditions, because this ability of dealing with things and events lies on their biochemical structures.

The process, which appropriates the language, for example, was essential to support the human development along its history, because it allows to create a World Reference System, due to the fact that cognition and language are processes that overlap, by itself, the constitution of a subject [26].

The ideas about intelligence have been expanded in order to become possible to face them as a part of emotional attributes, like natural intelligent systems.

The books "Emotional Intelligence" by Goleman [9] and "Descartes' Error" by Damasio [7], have greatly influenced such current point of view about intelligence, stating clearly that the reasoning approaches and moves Human Beings to take their decisions, pass through the "ambiguities of their judgments", normally based on their momentary behavior.

Goleman found out that if only associating intelligence with IQ (Intelligence Quotient), and also to genetic factors, can be a so close view of the reality.

Damasio has shown that the reasoning is inseparable from the emotions because the neuronal circuits, responsible for both, operate simultaneously, and so, are submitted to a law of uncertainty, because the perception of any scenario can affect our emotions, and so, disturb a clear reasoning about information which should be sent to the neuronal processing within floating patterns that concern to such moments and their psycho-emotional interferences.

Based on his extensive knowledge over brain processing, he presented a clear explanation about how reason and emotion interact, one another, to create decision-making processes, in order to plan how to act, even though many times, due to the speed required to acting, it is not possible to infer about its consequences.

Emotion and reasoning are adaptive mechanisms responsible for social adjustment of persons.

Without emotion there is no decision, consequently, neither action, because to take a decision the hippocampus must be connected to the right frontal lobule; otherwise the brains do not process a hormonal distribution appropriated to a specific scenario or situation.

Looking from the same point of view of the People with Disability, it is necessary to feel their difficulties in perceive tangencies or intersections of events that happen in some contexts by where they pass through, that could represent greater or lesser degree of importance, depending on the nature and severity of sensory losses: motor, visual, auditory, tactile and gustatory.

Several authors noticed the existence of a deficit in the communication and they suggested an AC to support a possible interaction of normal people with these with hearing deficiency [4,27,28].

The primary task to map the behavior of deaf persons, was to establish how they define their relationships with the world in which they are inserted, and find an easiest way to reach their emotions within their silent world, in order to map them and build fuzzy sets that can represent how could be their answers when submitted to specific

sensory stimuli. How could we translate a sign language into an emotionally measurable evaluation? Otherwise, we will remain in a complete silence.

A set of rules that constitute a Fuzzy System will evaluate each perception of a deaf learner, in order to correct a transience, which can happen among their five senses, when imposed by the environment and also depending on their specific and momentary needs, that can vary along a certain time.

The related processes at our five senses, are in a certain way, directly linked to learning, and are interpreted in a particular area located in the cerebral cortex [37].

And so, the objective of applying fuzzy sets regards to only reduce the ambiguities concerning the way by which their brains receive and reduce data from the exterior transforming them into a hormonal distribution that represents a specific behavior when facing challenges to win, such as emotional, psychological, difficulties on the contents, fatigue, ergonometric conditions of the installations and some impacts caused by extemporaneous information.

To develop a consistent fuzzy set, it must take into account a historical social revision of each learner, whose focus regards not only to the subject of the programmatic content, but the cultural context, defined as a social movement formed from a linguistic minority opposite to dominant ideology, in which such people are immersed, and consequently submitted to its conditions and concepts [3].

Such kind of persons, normally, build around them, a protection, which can look like a fence, because these persons have a lot of difficulty to maintain a normal relationship with those said as normal, due to several reasons being one of the most important the "embarrassment regarding to be viewed like a fool by the others" as a discriminatory act.

By choosing Fuzzy Logic and Sets to implement the correction of uncertainty, imprecision and ambiguities that lie on the unknown universe of these persons, will facilitate the understanding about their range of possibility to increase their social inclusion and feel themselves as a normal and productive member of a fair society.

The gray and the doubts that surround them within their universes, will be handled by a mathematical and computational modeling which will suppress these big fences that keep us so far from an understanding about such a silent world, i.e., how care their silence without breaking their privacy and individuality.

Based on the above philosophical support, it is possible to assure that, the research will pass by a linguistic identification, due to the fact that any syllogism must apply lexical combinations, in order to satisfy the concepts, of apodictic, dialectic or sophism.

In the other hand, the deaf, that cannot hear and consequently do not speak very well, and so, how to connect with them? How to feel their emotions only by a sign language, so cold and impersonal?

Normally the communication is made by speaking and hearing, but within the world of disability it is necessary to employ an alternative means, which can be done by signals, images or drawings.

To transform this collection of words and signals into a communication tool it signalizes to a set of "possibilities" instead of "probabilities", because the universe which contains such elements is not a finite one, but in permanent state of expansion and retraction, to thus, be able to capture the emotional state of deaf person, being in this case useful to apply fuzzy sets, to best understand and perceive in which part of the nebulous set lies some feeling hidden of a learner.

It is universally acknowledged that vague information exists in human thinking and natural language. Fuzzy set proposed by Zadeh [29] is a powerful tool to capture imprecision. In the past few decades, fuzzy set theory has been successfully applied to various fields, such as control, decision making, and image processing [30-36].

2. **Building Fuzzy Interfaces.**

2.1. **Where and how it will act.** A first task to start the building of such tool lies on an understanding about which point and when is necessary to introduce the factors of corrections in order to suppress imprecisions, uncertainties and ambiguities concerning to a sequence of perceptions about the stimuli issued by the environment.

According to [21] a mental process to get answers and take decisions concerning to specific scenarios, can be divided in six phases: observe, perceive, infer, concatenate, decide and finally act.

The first one represents the contact of some person with something that which takes him by surprise, and depending on his curiosity or interest, he starts the process of understanding by observing and collecting data about what awaked his attention.

After well identified, the boundary conditions and what that event or occurrence can represent to his behavior, his brain can discard the task of thinking about it, because it can have no interest, no risks to his security and does not aggregate any knowledge, being considered as already known.

If it decides to go ahead with the process, due to the fact that such perception can mean some importance, the brain orients the senses, aiming to advance in the second phase, to perceive, meaning goes in deepness through the accuracy of each point that can add value to a better understanding about the event or occurrence.

Once perceived each detail, as deep as needed, the information feeds the continuity of the mental processing, going through the third phase, which infers about the subject observed, perceived, and now must be inferred by the Natural Neural Networks.

This capacity of infer differs Human Beings from the other irrational animals, because it allows us to build syllogisms and so, construct many bases of reference allowing us to recognize each repeatable evidence and arrange their interrelations within a specific and peculiar method, but that can be recognized by others, creating the possibility of communication by mutual and reciprocal understanding.

However, only to infer does not mean to be able to get answers with some precision, and our brains have advanced forwarded in sophistication and developed a fourth phase, which executes a concatenation about what was inferred, meaning arrangement and grouping of many steps of possibility of decision according to its membership, in order to offer choices that will guide the decision about the event at processing.

Thus, our brains only offer a set of choices built according to their own syllogisms and stocks of knowledge, and that have been trained along the years. However, in a fifth phase "we are asked to participate in the process", i.e., assume the responsibility to choose, what will be the best decision among those that have been offered by our brains, and which will be the adopted.

However, as explained above there is no decision without emotion, due to the own physical structure of our brains that commands a hormonal distribution which prepares us to face reciprocal answers provided by the environment, and may be that, we will be called to change our decision, because after deciding, we pass to the sixth phase, which refers to put the decision running, i.e., to act.

If the meaning of acting is to put a decision running, obviously that it will be exposed to the environment conditions, and so, to a judgment of other involved persons, which can create a tremendous barrier to deaf persons, due to difficulties in the communication.

Looking at and thinking with a little bit more of deepness about these six phases, it may become easy to find where and how to act in the mental process performed by deaf persons, mainly due to their deficiency in hearing which blocks the access to their emotions, and so, does not allow us to feel correctly how could be their answers concerning

a specific situation perceived by any one of their senses remainders, which can happen any time along a relationship with them.

Firstly, it must be considered that, People with Disability, in our case Deafs, need an interface of communication, a signal language, which can be provided by a teacher or by a computational system.

However, what changes when it changes the sense with deficiency? Only the choice of a best way to assure that such person has known about what is going on when they are submitted to sensory stimuli, and more important, how to be sure about the completeness of their answers, taking into account exactly how they feel when facing a set of external stimuli and how such sets could change their metabolic arranges.

The uncertainties exposed above, can be attributed to the reliability of incoming or outgoing data collected from the first interaction with such kind of persons, and represent the challenge to be won by a fuzzy set and continuous act to a Mental Architecture Scanned – MAS.

Synthesizing the understanding about the intersection among the six phases of a mental process and the above identified uncertainties, it is possible to determine "where and how to act" to align them, performing this task by means of a reduction of the sampling space of the boundary conditions, that can affect them, keeping in mind well map the universe of perceptions of such persons when studying and learning in some pedagogical program of teaching, but not limited to this boundary conditions in order to extend the whole process to other similar situations involving People with Disability.

At this point it will be very important to emphasize that the learning process, does not depend only on the level of healthy or disability, but mainly on the curiosity, interest and the quality of presentation, and that can wake up the learner for the daily applicability of some subject, judged by him like useful, i.e., gains in their quality of life as a possibility of a social inclusion, for example.

The search for this Universe of perceptions identified four kinds of conditions or information that can affect People with Disability during a session of study, such as: psycho-emotional, fatigue, conditions of the environment and the relationship or understanding of the subject of some session of study.

The psycho-emotional refer to those that can disturb a mental equilibrium of a learner, normally associated to personal physical constraints and daily behavior within a global context of their lives.

The fatigue regards to the available energy of a learner, which depends on his behavior along the day, and also on the consumption, due to the psycho-emotional information regarding its contextual importance, which consumes a lot of energy, depending on the mental activities to process them.

The conditions of the environment regard to the ergonometric quality: internal colors, luminosity, temperature, humidity and so on.

The relationship and understanding of the subject, regards to the interest of him due to its utility on his daily activities and also to the quality of presentation of the programmatic content.

Looking at these four kinds of information it is possible to perceive that there is an intrinsic interdependence among them; due to the fact that, once information has been already perceived and has been passed by the mental process, it can affect another one, and so, disturb or recompose an eventual situation in which the learner can be living at such moment.

For example: a learner receives the information that someone in the family will arrive tomorrow. Such situation can be seen as good or bad news, depending on her relationship with such family member. If he loves her so much, and such love is reciprocal, her visit

will bring a big satisfaction; otherwise it can represent some disturbance regarding his behavior.

Obviously, such information will affect, directly or indirectly, the other three kinds, of a way for best or worse, and to evaluate how it affects the behavior of a learner, the Fuzzy System will provide the answer that will correct any uncertainty, imprecision or ambiguity regarding a specific event, in order to feed the next phase of the mental process which is performed by a set of Artificial Neural Networks.

After well defined how Human Beings can process their relationships with the external world, by using their five senses, as well how their deficiencies can affect and disturb the behavior instantaneously, it is possible now, start the definition of a complete fuzzy sets that will deal with the appropriation of "memberships (μ)" and create the rules that can start the interpretation of any information regarding a specific learner who has been mapped, to whom the answers will be directly oriented.

And so, each deficient learner will have his own set of rules, in order to minimize losses in the answers and spend actions in a wrong direction.

The major findings of this item were: a mental process can be considered as similar as possible by persons with or without disability; learning rates do not depend on a specific deficiency but can be associated with level of relevance and interest; the uncertainty, imprecision and ambiguities lie on the phase of "inference" and not on the "perception"; the information that can affect a learner in a session of study can be divided within an interdependency relation, from that it is possible to build a set of Fuzzy rules that can show a certain transiency of a perception by the senses, and considering these transients identify how to correct them to input in a Modelling Architecture Scanned.

2.2. **Building the fuzzy sets.** Another important factor regards to a peculiar and particular characteristic of each person, which will be designated by "specific speed of transience".

This factor will be responsible to signalize how the behavior of a person can vary, according to its metabolic interests, processed automatically by our brains, i.e., as far as an environment changes its own conditions while a person transits by it, the way of such person perceives and goes ahead into a mental process, the answers vary in an appropriate speed, in order to adapt him to face new challenges instantaneously, due to that, his senses perceive a big amount of information and must decide and act in real time, according with a metabolic configuration defined by our brains.

By applying this factor regarding to a speed to perceive, infer, concatenate, decide and act, it will be possible to introduce in fuzzy sets, a "dynamic component", and so, obtain answers closer to a reality lived by a learner, as processing in real life: dynamic with a specific transience.

Obviously, People with Disability present different speeds, depending on the severity and kind of their deficiency when perceiving or receiving information, but their metal process happens in an appropriate speed, within their limitations and level of sufficiency. This perception can change the paradigm of some computational tools, that work statically, and now it will be possible to create a dynamic to decision-making processes.

As shown above, our fuzzy sets must supply support to the interaction among the four kinds of information perceived and communicated by a learner.

Each information or sensory perception can vary within four ranges, directly related with its emotional effects, over a specific learner, because our interest is to interact with the process of decision performed by such persons who live enclosed within themselves.

At any time information or perception can affect a learner, according to its specificity, and disturb the other three kinds, in a way that cannot allow any chance to return to

an already known behavior, even being to improve or worsen a behavior of such learner provoked by the environment.

And so, our fuzzy sets must interact the four kinds of information by applying so called Factors of Influence, that measure how much better or worse such information can represent the behavior of a learner.

Nevertheless, it is not enough to understand in a simplistic way, because Human Beings have an incredible capacity to adjust themselves to any situation, and normally pay for that, accepting the adjustments, as a way of compensation.

To perform such interactions, firstly we define a Direct Factor of Influence (Fi), which will represent "how much the Information perceived and communicated, influences directly each one of the other three kinds".

The values attributed to such Factors can vary according to its effects, i.e., if it improves or worsens the other three.

In the same way, the sets of the three other kinds of Information must respond about how they perceive, and if accept or reject such effects caused by the Information communicated, even that to better or worse, by so called Factor of Reciprocal Influence (Fir), that can be in the opposite direction of the Information perceived by the learner, depending on how he will be able to deal with some conflicts in order to maintain a break even point to his metabolic configuration.

Such interdependence allows to best understanding how the transience among our five senses can change the behavior of a person, with or without disability, being important the aspect regarding the speed of this transience, which shows a specific ability to deal with challenges, in real time.

Always, when some Information is perceived and communicated by a learner, the teacher must attribute to it a numeric value according with its classification and the respective Factors of Direct Influence over the other three kinds of Information.

And so, the fuzzy sets must be built to deal with three factors to know: kind of the Information, its membership (μ), and its direct and reciprocals Factors of Influence, respectively.

The kind is chosen among the four presented above and according to the "perception" of the learner, which will be subject to the interpretation of the teacher, who will submit the data to an evaluation by the system.

The values to be attributed to a membership (μ) of information must be chosen within one of the five ranges: very bad, bad, correct, good and very good.

The values must be supplied with three decimals and its ranges are shown in Table 1.

TABLE 1. Membership (μ) and values

μ	Very bad	Bad	Correct	Good	Very good
Values	0-0.255	0.245-0.50	0.45-0.55	0.50-0.755	0.745-1.00

It should be noted that the ranges of values are overlapped, due to the fact that in each boundary lies on the subjectivity of analysis to punctuate some Information, whether it be by the learner or by adjustment of the teacher.

When Information is identified in such condition, increase the ambiguities and the way to take a best decision, i.e., what is the transience from very bad, "low" to bad "high"? It means the Information can belong to both ranges, fluctuating from "very bad" to "bad", and this will be corrected by the adherence function.

Once well identified and punctuated some Information, start the second step, which means to establish the Direct and Reciprocal Factors of Influence.

To punctuate them, they are identified from "weak to strong factors of influence", which can identify how such Information affects the other three, that can change a metabolic status of a learner, to disturb his current activity.

These two factors are not related directly one to another, but only in a way of "reciprocal double exchange", meaning that they are independent between themselves.

In such way, Information can present a factor of influence considered as "very good or strong" directed to another kind of Information, but reciprocally, such Information can be affected in a wrong way, and so, answer that its Factor of Reciprocal Influence lies in a different interval of evaluation: very bad or, simply bad, for example. These differences can change the equilibrium of the whole system.

As a tangible example, considering that in a company the Technical Department has found out a very good software to improve the production, and also, with a compatible cost, and so, Information with a Factor of Influence "very good" taking into account only the technical matter. Even though the cost and commercial conditions are very good, the Departments, Administrative and Financial, have no funds reserve to purchase this software, answering with a Reciprocal Factor of Influence "weak", "bad or very bad".

This freedom in a relationship among the four kinds of information creates a set of possibilities to interact the numeric values that can map a behavior of a learner, and more, to know in a real time where are his deficiencies, and correct any deviation of conduct, just in time.

This process of logic provides a double way of transience and can map any change in the behavior of a person, when in transit by any context, in our case, the teaching and learning.

In order to punctuate these factors, it can be used the same values shown in Table 1, with three decimals, i.e., 0.254, 0.823 and so on.

The values attributed to these factors are not submitted to an adherence function, due to the fact that they are linked strictly to a concrete perception about the scenarios that contain them, concerning to each learner while studying any programmatic contents, guided by a teacher.

However, the punctuations attributed to any perceived and communicated Information by a learner, must be evaluated by an adherence function, in order to correct its ambiguity mainly because this value starts the analysis process and is attributed by the learner and adjusted by the teacher.

The adherence function is represented by a random curve to each interval of classification: very bad, bad, correct, good and very good.

This perception gains more importance, when arrives near the point of transition of one interval to a subsequent, where there is an overlapping of values, so called "gray zone", even because it is very difficult to define which will be the behavior of the learner, when facing some challenge created by Information classified in one of the five intervals shown in Table 1.

In this way, it will be provided a set of functions that will deal within these intervals aiming to be as near as possible to the natural mental process, considered as divided in six phases as shown before, arriving with this approach, into the phases of "inference and concatenation", and with the results of such analysis take a decision which will aid a deaf learner to an adjustment of their deficiencies along a session of a program of study.

Such intervals represent the "gray zones", and at the classification of a "correct Information" lies the most nebulous, because near this point there are three regions overlapping: from "bad low", passing by "exactly correct" to a "good low".

How to adjust exactly into which region belongs to some particular Information?

Once, well identified Information with its respective membership value, a few factors can influence the exactness of this punctuation, such as: environment situations, emotional engagement and physical conditions of the learner.

In order to adjust such normal deviations considering that this representation deals with the sensations of Human Beings, this research proposes a random function of adherence, aimed to increase a nebulous interpretation about the matter in study and avoid any partiality in judgment.

In such way, this function of adherence increases the level of freedom in the phase of "inference" about some event, which has been "observed and perceived" by any person, with or without disability, going to the direction of basic premises of Fuzzy Logic.

The weightlessness of the brain processes that perform many tasks simultaneously, also leads us to discredit in a "totally probabilistic world", nearing us to a "possibilistic world", which seems more compatible to a random and nebulous analysis.

When dealing with People with Disability, this perception becomes more important, to access their emotions by simply understanding about how Information can touch their feelings, and perform a sense of judgment based on emotion, responsible to any decision making process, due to a loss in the quality of one or more senses and difficulties of communication.

And so, the fuzzy sets must provide a support to analyze "perceptions and emotions", based on a set of rules that interact, direct and reciprocally, a numeric punctuation obtained from the perception of a learner with disability, and also a procedural routine responsible to reduce the deviation in the evaluation of its values, performed by a random function of adherence which increases the freedom of the outgoing results, nearing us to a best understanding about one specific learner, opening doors to increase their possibilities to a social and cultural inclusion.

Such functions can also aggregate the interference of the "speed of sensory transience", which will provide a dynamic feature to the whole system, running in real time by mapping the changes in the behavior of a learner with disability.

2.3. **The MVFS and fuzzy sets diagrams.** As described above, it is possible to perceive that our brains, decide based on many kinds of Information that are processed simultaneously and according to its interdependence the decision can change along a short space of time, depending on the balance of judgement and such interdependence between specific Influences, meaning: what is worst in a certain time, can be changed quickly to a better condition.

Thus, it is not enough to try to model a mental process of inference, dealing with an insufficient number of degrees of freedom, because normally, natural or designed systems have at least more than two parameters of judgement, similar as in the Nature.

How to supply this necessity of increasing the number of degrees of freedom?

Perceiving what we are dealing with, integrating with such perception, how the way whereby is, their relations of dependence happen.

The fuzzy set of Information has four elements, and when has been chosen the one that represents a perceived and communicated event, which will start up the process, automatically it defines the arrangement of elements that compose the Matrix of Interdependencies, due to that, it can disturb the equilibrium of the behavior of some persons.

Being so, such Information receives a value chosen within the defined Ranges for its classification: very bad, bad, correct, good or very good.

Figure 1 shows how to classify some perceived information, according its effect.

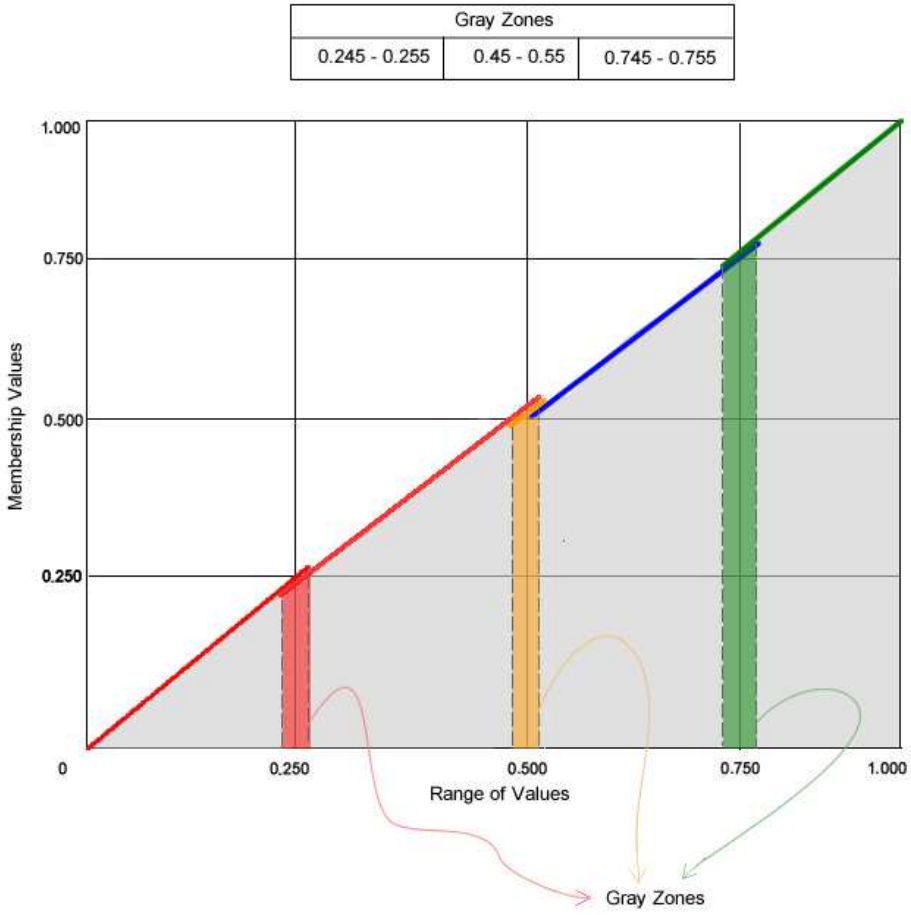

FIGURE 1. Memberships and the gray zones

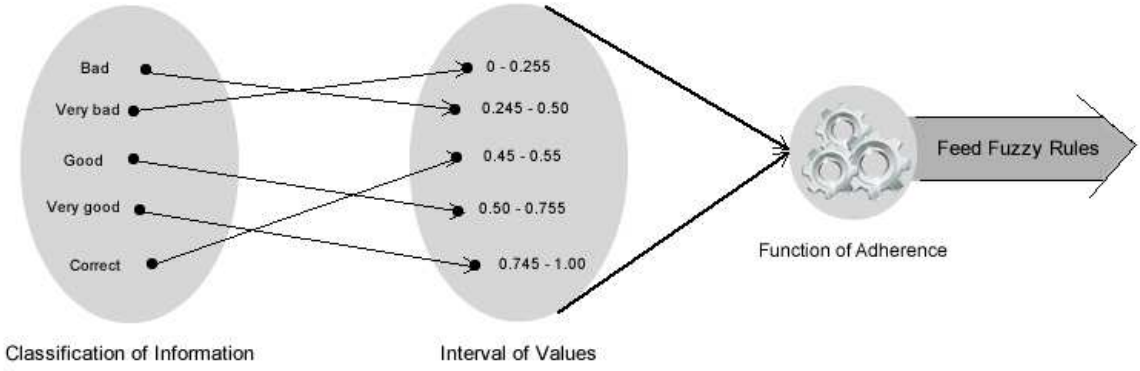

FIGURE 2. The fuzzy sets and function of adherence

By such way, there are five possibilities to classify Information that will interact with the other three in a direct way, by applying the Factors of Influence, that must be valued by the same five Ranges, i.e., very bad, bad, correct, good or very good.

Figure 2 shows how happens the relations among the classification, type and the correction executed by the Function of Adherence with outgoing will feed the Fuzzy Rules.

Simply by better understanding this first step of MVFS, it is easy to perceive that there are more than two polarities, showing that from the point of view of natural processes, it becomes nearer to the ambiguity of a mental process of inference, i.e., processes of analysis of decision under uncertainties that are also affected by the polarity of such multidimensional interactions.

In the other hand, there are the Reciprocal Factors of Influence, concerning the other three kinds of Information that can vary in the same Ranges: very bad, bad, correct, good or very good, meaning how they would answer to such emitted stimulus, by the perceived and communicated Information.

These Reciprocal Factors must also be defined regarding the relation with the other kinds, i.e., even though Information has received a direct influence from a perceived and communicated Information, it has the same possibility and obligation of answering positively or negatively, one another, generating at this moment the other elements that will compose the Matrix of Interdependences.

Figure 3 shows how is performed the relations among the fuzzy set that will provide the data to compose the random matrix.

Note that are shown the direct and reciprocal influences among them.

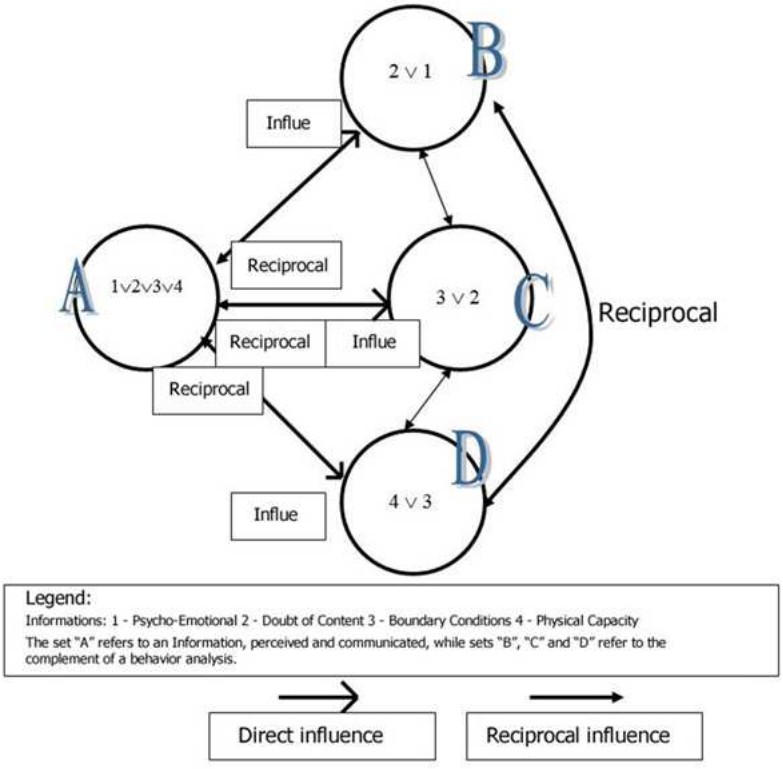

FIGURE 3. Structure of fuzzy sets Interdependences

The outgoing values of the fuzzy sets able the building of a Random Matrix, that will supply the data to arrange the Matrix Orderly of Interdependences. The data correct the ambiguities of perception, evaluated by the learners and teachers. This Matrix has four lines and twelve columns, that represent the results of the relations between the perceived Information which starts the process of analysis, and the columns refer to the reciprocal answers from each other kind of Information, combination of the type and kind of them.

Table 2 shows the combinations among the four kinds of Information, represented by its fuzzy sets to that they pertain.

Table 2. Random Matrix

0.364	0.307	0.310	0.251	0.390	0.376	0.242	0.177	0.415	0.441	0.493	0.094
0.105	0.394	0.257	0.124	0.440	0.033	0.477	0.432	0.424	0.469	0.184	0.396
0.395	0.041	0.448	0.466	0.169	0.394	0.002	0.097	0.427	0.196	0.237	0.253
0.352	0.453	0.059	0.437	0.208	0.004	0.247	0.104	0.232	0.032	0.275	0.067

Note: This Matrix serves of base to arrange the Orderly Matrix and the data come from the fuzzy sets rules of evaluation.

In order to attend this work of research such Matrix will be of 4×4, but as an extension of applicability of the MVFS, as a general-purpose approach it can have more degrees of freedom, and so, the order of the Matrix will increase following the dimensions of a system to be subjected to such analysis process of decision. An example of Matrix of Interdependences can be seen in Table 3.

Table 3. Matrix Orderly of Interdependences

	IP	IC	ID	IF
IP	1.0	0.394	0.294	0.200
IC	0.500	1.0	0.499	0.499
ID	0.492	0.397	1.0	0.487
IF	0.496	0.498	0.478	1.0

Legend:
IP - Psycho Emotional
IC - Boundary conditions
ID - Doubts of Content
IF - Physical Capacity

Note: The Orderly Matrix arranges the values in a decreasing way from the left to the right keeping the main diagonal with unitary values and the secondary with the smaller multiplicand.

This new approach of perception of the environment conditions and its stimuli, allows to enlarge the possibilities of dealing with many kinds of systems, closed or opened, due to the fact that its capability of adjustment within any environment conditions refers to the accuracy about how the managers perceive, which is the Domain of Knowledge applicable and begins to think how the pertinent syllogism works within the system.

Following, it will be presented how the fuzzy sets were built in order to meet the requirements as explained above, and how such conception works within the Domain of the possible interactions among the classification and ranges of respective values of each one.

The Domain is represented by an area below of the diagonal of a square, drawn in a Cartesian plane varying in the "X" axis from 0 to 1, divided in five parts that show the Ranges of Values, as well as in the "Y" axis which shows the membership values, also varying from 0 to 1, divided in four intervals.

The diagonal is monotonic ascendant from zero to one, divided in five segments that represent each range of values assigned to Information: "very bad", "bad", "correct", "good" and "very good", identified by different colors.

In synthesis, the MVFS links the perceptions about any Information provided by the environment and assigns to them numeric values that represent how the mental inference results can change the behavior of a person, being in this paper People with Disability.

All Information belonging to an event can be attributed a numeric value to represent it, in order to link it with a global interaction with the environment as a way to map the behavior of a person belonging to a specific context.

To show an answer about some Information regarding an event, the MVFS calculates based on fuzzy sets, with or without overlapping, creating the so called "gray zones", in which lies the biggest ambiguities, to define a correct value to classify Information. The graph that represents the Gray Zones, is illustrated in Figure 1.

To avoid, such deviations before start the process was foreseen a Function of Adherence in order to correct an eventual duality. The action of the Function of Adherence is illustrated in Figure 2.

Such Function of Adherence can vary, depending on the system boundary conditions, showing its flexibility in counter-position to another similar process.

With this approach it is possible to mount a Matrix of Interdependences, which represents how some Information can affect a person's behavior, with or without some disability, by interacting the fuzzy sets to where belongs Information and its Factors of Influence against or in favor of the equilibrium of the context where it happens, as shown in Table 3.

From this Matrix it is possible to extract a list of conclusion about any change in the behavior of a person or global context, due to the fact that the evaluation of them is based on fuzzy sets that have a Domain within the Range from the true to false, not only as a Boolean or YinYang perception, being thus a Multipolar approach.

In Table 4 are shown the main data about an example evaluated from the matrix Orderly of Interdependence.

TABLE 4. Summary of data from Orderly Matrix

Factor of Impact	50.66140363253051
Average of Column 1 (P)	0.496430942273265
Average of Column 2 (D)	0.42996881270189596
Average of Column 3 (C)	0.4240787876468686
Average of Column 4 (F)	0.3956838773189077
Average of 4 columns	0.4365406049852093
Determinant	0.41508205388553543
Effort	0.42515154003312083
Consolidation	0.44567918141000434
Phase	0.4350154724090759
Evaluation Test	0.4356044749145786
Didactic Advancement	0.4450901789045016
Social Inclusion	0.4277802569464463
Final Validation	0.44567918141000434
Behavioral Zeal	0.4277802569464463
Application of the Learning	0.4412834569801708
Learner	0.43463724402304393
Teachers Participating	0.44187245948567355
Team Involved	0.44910767494830317

2.4. **Theoretical support for cognitive concepts.** In order to support the breadth of the proposed MVFS, which represents an extension of a Bipolar-Valued Fuzzy Set – BVFS, it is necessary to know how the cognitive process happens and also, how it can be mapped in a fuzzy set; otherwise this faculty assigned to Human Beings could not be

evaluated by a computational tool due to the fact that such activities are performed by our brains within a turbulent flow of tasks and thus, the cognitive function could be left aside despite its relevance to our behavior and learning process.

Results in cognitive psychology have pointed out the importance of bipolar reasoning in human cognitive activities [5]. It even seems that positive and negative effects are not processed in the same area of the brain [8]. Experts in different fields, such as database querying, decision making, classification have noticed the importance of bipolarity [23].

In fact, according to Han et al. [12], fuzziness and bipolarity are two independent but complementary notions devised to model different aspects of human thinking. The former focuses on linguistic imprecision, while the latter emphasizes relevance and polarity of information. Two notions have gradually shown high relevance in recent research. Some exploratory researches have demonstrated the merit of combination of the two notions and some instructive results have been obtained [22,24].

To assure the context of the study of the case presented following is necessary to understand how happens the linkage among teaching, perception, cognition and learning within a context of brainstorm.

The approaches adopted in this research to view this perspective, when associated at the development of a Pedagogical Model, propitiated a better understanding of needs of a Teaching Program for the People with Disability. It also enabled an instant analysis of occurrences throughout its application, planned or not at the initial programming. In this research, was used model Fuzzy Cognitive Maps.

The Fuzzy Cognitive Maps – FCM, has been proposed by Kosko [14] based on the work of Axelrod [2]. Axelrod developed a mathematical treatment, by operations with matrices, for their cognitive maps.

A cognitive map is a way the person or group represents your thoughts or beliefs on a limited knowledge domain. Such thoughts are expressed through words or linguistic expressions, joined by single bonds of cause and effect.

This map can be considered as a complex system mathematically modeling the "belief structure" of a person or group, allowing to infer or predict the consequences that this organization of ideas causes in the universe represented.

Kosko adapted the mathematical treatment of these Axelrod maps for a mathematical treatment using Fuzzy Logic. The Fuzzy Cognitive Maps – FCM like the cognitive maps of Axelrod, are bidirectional graphs (digraphs), but the numerical values are variables or fuzzy sets.

Figure 4 shows a generic FCM with generic concepts (C1, C2, C3,..., Cm and Cn) and weighted edges (arrows) among them (w_{12}, w_{21}, w_{mn}, w_{nm}). Each concept represents a fuzzy set or a fuzzy variable, and the edges represent a fuzzy causal relation between the concepts. This kind of relation usually represents three possibilities: no causal relationship (no link between concepts), positive causal fuzzy relationship, or negative causal fuzzy relationship. This illustrative graph can be translated as a matrix where each element corresponds to a value of the edges among the concepts. Figure 4 shows this matrix $W_{n\times n}$.

The FCMs are a good way to represent complex systems that are not well defined. They combine some advantages of modeling through Neural Networks and Fuzzy Logic. The "note" of these graphs are linguistic concepts, represented by fuzzy sets, and each "node" is associated with each other through "linkages". Each of these "links" is associated with a numerical weight, representing a fuzzy variable related to the level of causality between the concepts.

In building the FCM it was necessary to gather information on the subject matter through interviews and questionnaires applied by experts. After collecting information,

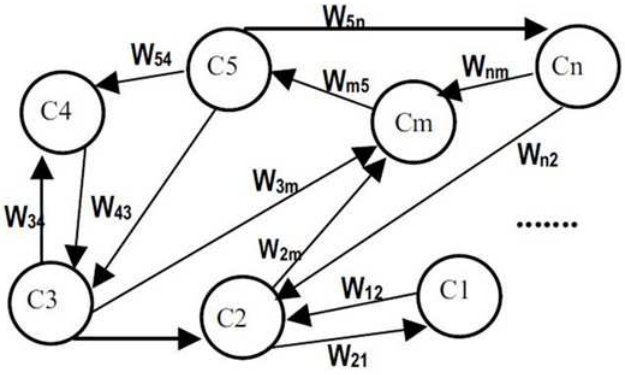

FIGURE 4. Generic example of Fuzzy Cognitive Map. C1C2...CmCn = concepts; W_{ij} = weighted links (causal relations). (Adapted from Stylios and Groumpos [20])

		EFECT ⇓						
		C1	C2	C3	C4	...	Cm	Cn
C	C1	w_{11}	w_{12}	w_{13}	w_{14}	...	w_{1m}	w_{1n}
A	C2	w_{21}	w_{22}	w_{23}	w_{24}	...	w_{2m}	w_{2n}
U	C3	w_{31}	w_{32}	w_{33}	w_{34}	...	w_{3m}	w_{3n}
S	C4	w_{41}	w_{42}	w_{43}	w_{44}	...	w_{4m}	w_{4n}
E	...	...	...	...	...	...	...	...
⇒	Cm	w_{m1}	w_{m2}	w_{m3}	w_{m4}	...	w_{mm}	w_{mn}
	Cn	w_{n1}	w_{n2}	w_{n3}	w_{n4}	...	w_{nm}	w_{nn}

C1= concept 1
C2=concept 2
C3=concept 3
C4=concept 4
...
Cm=concept m
Cn= concept n

FIGURE 5. Representative matrix of the FCM shown in Figure 4

a specialist managed the content obtained and set the most appropriate FCM for that matter.

When different experts are consulted, they may differ in their opinions about the numerical weight of "linkages" or concepts which are really relevant. They may agree or not with a particular organization or even the overall balance of the full FCM. Therefore, the knowledge engineer can add the FCMs thus providing a possible solution to the problem. The superposition of FCMs of each specialist tends to override conflicting opinions and having the consensus [15].

FCM has many advantages in the modeling of cognitive processes, because this tool is able to simulate parallel operations (feature of Neural Networks) and dealing with misconceptions by Fuzzy Logic.

A concept ("node") may represent a "mental structure of knowledge" ("Mental representation") aggregating various types of information and do not have a precise limit. That is, a fuzzy set, due to their characteristics, can be a good option to model the mental structures.

By definition, in a FCM a "node" – concept – is a fuzzy set. In addition, the integrated processing and simultaneous of various information in emotional episodes fits very well to the model of a digraph. Therefore, it can be concluded that the FCMs have great potential for proper modeling of "mental reality".

The approach of cognition by means of Fuzzy Cognitive Maps has great potential in the modeling of psychological processes. However, this approach enables the development of many models. Then, it will be defined what "nodes" and "links" of FCM represent in this approach.

The "nodes" of FCMs represent concepts expressed by a word or verbal expression. This paper proposes a model for the cognitive processes. Therefore, the chosen concepts are linguistic expressions about this reality. At the mental level, such processes activate various knowledge structures or of the information highly interconnected. Here, all "knowledge structures" presented in the mind of an individual will be the set universe of their "mental representations". This set universe is composed of many subassemblies, according to a particular characteristic or considered organization.

Thus, an example of restrictive analysis would be: considering an individual with a certain level of math instruction, it may be considered as its universe a set of numbers, the set of complex numbers, which presents various subsets. These subsets could be of the following numbers: reals, integers, prime, irrationals, multiples of two, etc.

In the example, there are many subsets and intersections between them. The same elements may belong to different sets, or between some sets, there is no intersection. This is a typical case of classic sets (crisp sets) where the elements belong or not to a certain set. Already in fuzzy sets, the relevance of an element a set is a function, so, the degree of membership of an element to a set can vary continuously between belonging and non-belonging. So there is not a well-defined limit of set.

Returning the "mental structures" or "mental representations", they will be taken here as knowledge organizations. Such structures ranging from sensory representations up to complex structures and abstract, as for example, the semantic memory, the memory of procedures, the episodic memory (model of Tulving), the goals, the model of the I, the model of the others, the model of the world, the emotional reactions, etc.

In modeling proposed here, these structures are subsets of the universe set of all "mental representations" in the mind of an individual. Such subsets are fuzzy, because they do not have a limit well defined and have many intersections (common information) each other. They are quite comprehensive and represent "class of concepts". The instances of the classes of these concepts will be the "node" (concepts) of FCM intended. Such concepts will represent some emotional aspects, motivators, of personality, of the goals, of the I, etc., present in the "knowledge structures" to an individual or a group of individuals.

These concepts form small networks that add various types of information (sensory, episodic, linguistic, etc.), but are identified by means of a word or linguistic expression. They are highly interconnected forming a wide network of information. Have the "links" of the FCM modelling these interconnections, indicating a numerical value diffuse as a causal relationship between the concepts. This relationship represents the degree of intersection (degree of subset hood) among subsets/concepts, or better, how much it has similar subsets with each other in terms of relative of cause and effect.

One of the proposals of this work was to define the concepts based on specialized bibliography of Psychology and to search expert opinion about the causal relationship between the concepts chosen.

Whereas that FCM is a very appropriate tool for modeling of the mental reality, in particular of cognitive processes, was defined a methodology to building this model with the following steps:

1. Definition of concepts and their number;
2. Development of a questionnaire to collect information on the causal relationship between the concepts;
3. Application of the questionnaire to a group of specialists;

4. Definition of the FCM based on responses obtained; and
5. Analysis and evaluation of results.

Concepts were defined for the "node" of the FCM. They are based mainly in the memory model of Tulving [25], in the model SPAARS of Dalgleish and Power [19], in studies of Reeve [19] and in the basic needs of the human being defined by Murray [17].

Each Concept is an instance belonging to one of seven classes of concepts: emotions, aspects of personality and motivators, meta-goals, meta-actions, aspects of "I", expectation, and aspects of working environment/school. The first six classes were chosen because they represent important factors related to the emotional and motivational processes. And the last class represents a more specific context, in which cognitive, emotional and motivational processes are being analyzed. The definition of a context is fundamental to strengthen the extension of the meanings of the concepts.

To obtain the weight of the causal relationship between concepts (value of "linkages" of FCM), was established the possible combinations between concepts. The relations were established with a diffuse gradation, being proposed the following gradations: Very bad, Bad, Correct, Good, Very Good.

From this establishment was made a numerical computational-processing of data. Several numerical approximations were tested to evaluate the numerical trends of system and enable the correct interpretation of results. The results obtained in these numerical approximations were used to define FCM and computer simulation of the proposed model. From this simulation was assessed the interaction between the concepts and how they mirror the psychological reality studied. Were also addressed the numeric-computational issues involved and results obtained.

The modelling of the cognitive of these research processes was based on the concept that the senses are the gateway to learning in the human body, they assist in the capture of the most varied contents. According to [18], the ability of learning is accomplished by sensory cells, highly specialized, across the body or concentrated in so-called sense organs, forming what is known by senses of the human body.

The stimuli are captured by these sensory cells and taken to the brain via nerve impulses. On reaching the brain, the nerve impulse is interpreted as a visual sensation, aural, olfactory, and gustatory or touch.

In order to check the proposal of this paper, it implemented an experiment to deal with the sensitiveness of the MPVFS within a group of deaf learners, as presented following.

3. **Proposed Study of Case.** In this paper was held a Study of Case on "Cognitive Development for teaching People with Disability". A prototype was experienced in some instances, in the field of knowledge of physics.

Rules of Logical were built responsibles by the treatment of ambiguities and uncertainties arising from any external information perceived by apprentices with Disability, that might change your behavior on the study of a particular programmatic content.

For each apprentice inserted in the system, was assigned a variable to represent your initial conditions, calculated according to some factors that characterized their respective profiles of cognitive ability, of relationship, of vocation and sensory degradation.

This factor was monitored along the transmission of specific knowledge. According to the evaluation of the nature of some Information perceived over a period and their respective impacts on an apprentice. With that, the educator was able to establish changes or adjustments in his conduct, as well as in its evaluation criterion.

For each apprentice assigned it himself a curve of assessment and control, distributed in 4 phases (Pedagogical Structure, Temporal distribution, application of MAS and consolidation), that cumulatively added a state value according to each phase, until the final

limit value, established in the beginnings of a period of knowledge transmission, treated as value of final state, which represented the potential expected of the apprentice.

4. **Experiments and Analysis of Results.** This preliminary research (not confirmatory research) is proposed to evaluate experiments performed through prototype applied in a Study Case in the field of knowledge of physics.

The experiments were accomplished in a state school, by one of the institution's teachers.

In carrying out this experiment were watched 10 deaf students, representing the size of a sample, which according to [16], is enough to obtain meaningful and satisfactory results for a preliminary research.

The application is signaled for the use of certain pedagogical strategies needed for best performance of learning.

The use of video-lessons was adopted as learning support tool [10], because it verified the need to exploit the visual potential of the students.

At certain times of the lessons, the contents presented emphasized items of greater relevance for apprentices, according to the assessment of their cognitive abilities, making flexible the learning differences.

A differentiated assessment was used for apprentices. An evaluation object [11] was applied, making it possible and feasible the treatment of the contradictions [6], enabling the scope of expected capability of apprentices.

At all stages of the teaching and learning process, the Professor followed interacting with the prototype stating the following: the values for phases of the course; the nature of the information; and the factors of influence. The system has calculated the values of the evolution of the apprentice and also indicated which lines of action should be taken.

The process of learning assessment occurred in two periods, only in the second was utilized the prototype. It applied the technique of hypothesis tests [13] for analysis of the results of this preliminary research. The average allocated to students after each evaluated period are shown in Table 5.

TABLE 5. Average regarding the assessment of students

1° period	**2° period**
60	80

It appears from Table 5, the results earned by students in the 2nd period, after applying the prototype, are higher than those of the 1st period that, although obvious finding must be emphasized. It is believed that no other factor, in addition to the use of prototype, had influence on better productivity of students.

The hypothesis testing, statistical inference method used for analysis results in this preliminary research, consisted in assessing the population before and after the use of prototype, in order to verify the validity of hypothesis.

According to the technique, was defined as a null hypothesis (H_0), that students who have some sort of disability have the same ability to learn that an apprentice considered normal.

As hypothesis of equality (H_1), defined it as usage of prototype plays a role of effectiveness in the quality of relationship of teaching and student learning with disability.

Based on differences (d_i) (values before and after the use of prototype), it has been calculated the average ($\overline{D}$) and the standard deviation (SD). The method also considered the calculation of the test statistic (t) and the use of a supporting table called Student t.

According to the method, with a 10% level of significance (α), there is verified evidence from the increase in the value of the notes from the 1° to the 2° period, the rejection of the null hypothesis.

Thus, the null hypothesis (H_0) was denied and thus the hypothesis of equality was considered true.

By means of the results obtained through this preliminary research, one can infer that prototype, sustained in a similarity pscico metabolic metabolic momentary of the apprentice, plays role of effectiveness in the quality of relationship of teaching and learning.

Also, the cognitive faculty is intrinsically related to a need, and that the setting of learning depends on the shape and conduct by which presents itself enough for your understanding.

5. **Conclusions.** The major finding of this research lies on the perception about how it is possible to map a natural mental process, by applying computational tools integrated to a theoretical support of a logic which allows to deal with the same ambiguities, imprecisions and uncertainties, similarly as performed by our brains, in real time.

The research pointed out two possibilities: Fuzzy Logic or Paraconsistent and was chosen the first one, due to the fact that it allows to create overlapping sets, as so called "gray zones" and within its intervals provide value that can represent a possible status.

The main objective was to map the mental process of People with Disability, because till this moment there was no approach able to link the answers provided by their brains regarding the exterior world, and who live in a restrained environment of themselves, in particular case of this paper, the deaf persons.

By applying fuzzy sets concepts to map the four kinds of Information that usually can disturb a learner during a session of study, and that can act directly through their five senses, perceived and processed by their brains, it was possible to find a way to simulate out the results of interaction among the four kinds of Information, mainly those related with the process which adds the emotional with the rational, that at the end is responsible by the decision-making process, independently of the physical conditions of a person.

Therefore, associating the proposed Multipolar-Valued Fuzzy Set with a Matrix of Interdependence can represent an opening door to a Perceptive Management, due to that this understanding of the real world, passes obligatory by the care with the mapping of the context within we will work to perform a decision-making.

The words of order are: "perceive the "details" that involve some event, classify it according to a set of pertinence with the subject, choose an Interval-Valued that can represent the perception, and punctuate each Factor of Influence, in order to proceed with the analysis process".

Even after a deep search for any similar work to compare results to prove the gain of efficiency of what is proposed in this paper, as far as the authors found, no similar work has been found yet, in the available media, what allows to infer about the uniqueness of the contribution of this research.

However, Han et al. [12] guided the authors to propose a "n" degrees of freedom fuzzy sets so called Multipolar-Valued Fuzzy Sets – MVFS with a plus of a Matrix of Interdependence that allows to deal with many interdependent variables, being enough only increases the order of the Matrix, and consequently the number of the Fuzzy Rules.

Finally, the use of fuzzy sets concepts, proved to be sufficiently strong to support the modelling of a learner with or without disability when facing some challenges, mainly because our mental process which maintains our bodies in constant movement and equilibrium within an environment, even so evaluates simultaneously each situation eventually

faced, and establishes an appropriate metabolic pattern to face such event, and their external relationships, as well as simulate the decision-making process, similarly as a brain would do it.

In the near future, these authors believe that the development focused on the use of technologies that assist the learning process of the Deaf or People with another kind of Disability, will evolve naturally with the continued researches of these methodologies, and also by the emergence of others.

Therefore, the authors suggest the application of this research in other Domains of knowledge, for improvements and enhancements.

The authors also believe that by the implementing of the concept of "speed of transience", this proposal of an MVFS, will make available a dynamical tool aimed to follow up learners, with or without disabilities, enhancing their self-esteem, educational achievement, and yet, their socio-cultural inclusion.

The authors also believe that the MVFS can be extended to other systems that require a decision based on the Information analysis, perceived from the behavior of each context, obviously regarding their Domain of Knowledge.

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