

The ‘human intelligence’ linguistic variable is a potential fuzzy computational model for the natural language expression ‘human intelligence’

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Abstract. This paper presents a fuzzy, computational model for the natural language word ‘human intelligence’. This is a mathematical model that takes into account various interpretations of the word “intelligent” and enables comparisons between them for a given IQ index. The model is a linguistic variable mathematical model, built especially for the word ‘human intelligence’ and is called the ‘human intelligence’ linguistic variable. The model is constructed systematically along the whole paper. The first step consists of the representation of the word ‘human intelligence’ with a fuzzy set. This step is followed by the construction of fuzzy sets corresponding to the words obtained by adding different hedges to the word ‘intelligent’ (i.e. very intelligent, more or less intelligent etc.) The steps, which follow, use fuzzy logic operators and fuzzy set operations in order to further expand the set of different possible understandings of the word human intelligence. Along the whole paper, different examples are presented in order to illustrate the new element incorporated in the ‘human intelligence’ linguistic variable, and illustrate computation with the new added element.

Keywords: IQ index; linguistics variable; fuzzy set; fuzzy logic concepts; fuzzy logic operators.

1. Introduction. The natural language expression ‘human intelligence’ could not (even after it became an object of science) benefit from a classical definition, through delimitations of proximate gender and specific difference. Expressing actions and attributes of human been at the same time, faber and sapiens, the natural language expression ‘human intelligence’ is the intellectual capability of humans, which is marked by complex cognitive feats and high levels of motivation and self-awareness. Using their intelligence, humans are able to learn, form concepts, understand, and apply logic and reason. Human intelligence is also thought to encompass their capacities to recognize patterns, plan, innovate, solve problems, make decisions, retain information, and use language to communicate. The term ‘human intelligence’ has been present since time immemorial in natural language, enshrined in literature (apparently by Cicero) and characterizes (from various angles) the power and function of the human mind to establish connections and make connections between connections: it is what suggests inter- legere, bringing together two meanings - to discriminate between and to bind (to gather, to put together). Of all human abilities, the most specifically human characteristic is intelligence, given that it transforms biological man into Homo Sapiens. However, intelligence is not a material thing, but an abstract concept, being difficult to define. We can say that one analyzes the manifestations of intelligence, the faculties that define intelligence, but not intelligence itself. Taking into account on the above presented facts, it follows that the natural language word ‘human intelligence’ is fuzzy and inappropriate for computation.[1]-[93]

On the other hand fuzzy set logic provides a mean for dealing with ambiguity. As it deals with imprecise objects, it has been and, for a number of scientist, remains an unacceptable tool in the precise world of science. The success of

fuzzy logic surprisingly began with industrial applications including train control (Yasunobu and Miyamoto 1985), auto-focusing cameras (Shingu and Nishimori 1989) or cement kiln control (Holmblad and Ostergaard 1982). Fuzzy logic is used to describe, ambiguity and uncertainty in case of the fuzzy linguistic expressions, in a non-probabilistic (non-frequentist) framework.

In this, paper a specific linguistic variable that of the ‘human intelligence’ is constructed! This linguistic variable is build up along the whole paper. The first step consist in the representation of the word ‘human intelligence’ with a numerical triangular fuzzy set. This step is followed by the construction of numerical fuzzy sets corresponding to the words obtained adding different hedges to the word ‘intelligent’ (i.e. very intelligent, more or less intelligent etc.) The steps, which follows, use fuzzy logic operators and fuzzy sets operations in order to further expand the set of different possible understandings of the word ‘human intelligence’. Along the whole paper different example are presented in order to illustrate the properties of new elements incorporated in the ‘human intelligence’ linguistic variable and illustrate computation with the new added element. As far as we know for human intelligence such a mathematical construction does not exist. This is mainly the novelty in this paper.

In section 2, the meaning of the natural languish word ‘human intelligence’ during history is presented. **In section 3**, the measurement of ‘human intelligence’ and the meaning of IQ index during history is presented. **In section 4**, the fuzzy set description of ‘human intelligence’ is presented. **In section 5**, the effect of linguistic modifiers, in case of the natural languish expression ‘human intelligence’ is presented. **In section 6**, the concept of linguistic variable ‘human intelligence’ is presented. **In section 7**, extension of the kernel of ‘human intelligence linguistic variable’ by using fuzzy logic and fuzzy logic operators is presented. In the expanded context, the fuzzy logic operators and the fuzzy subset operations are also discussed. **In section 8**, results and discussion are presented.

2. What is the meaning of the natural languish word ‘human intelligence’? Intelligence has been defined and studied by each psychological school according to the general postulates of the conception of Man. The psychology of ‘human intelligence’ is closely related to the concept of individual differences in mental "traits" and the development of analytical tools. Throughout history, the meaning of ‘human intelligence’ has changed a lot. The evolution of ‘human intelligence’ refers to several theories that seek to describe how ‘human intelligence’ evolved in relation to the evolution of the human brain and the origin of language. [1] The timeline of human evolution spans about 7 million years, from the separation of the genus Pan to the emergence of behavioral modernity 50,000 years ago. Of this timeline, the first 3 million years concern Sahelanthropus, the next 2 million concern Australopithecus, while the last 2 million cover the history of Homo Reale (Paleolithic) species. Many features of human intelligence, such as empathy, mourning, ritual, and the use of symbols and tools, are already evident in the great apes, albeit at a less sophisticated level than in humans. There is a debate between proponents of the idea of a sudden emergence of intelligence, called the "Great Leap Forward" and proponents of a "Gradual Emergence" (continuous) hypothesis of ‘human intelligence’.

Theories of the evolution of human intelligence include: Robin Dunbar's Social Brain Hypothesis [2], Geoffrey Miller's sexual selection hypothesis (concerning sexual selection in human evolution) [3], The hypothesis called ecological dominance-social competition (EDSC) [4] (explained by Mark V. Flinn, David C. Geary, and Carol V. Ward, based primarily on the work of Richard D. Alexander), The intelligence hypothesis as a signal of good health and disease resistance, The hypothesis called group selection theory (this holds that organismal characteristics that benefit a group (clan, tribe, or larger population) can evolve despite individual disadvantages, such as those cited above), The hypothesis that intelligence is connected to nutrition and thus to status.[5] (this supports the idea that a

higher IQ in a person could be a signal that the person comes from and lives in a physical and social environment where nutrition levels are high and vice versa).

Theories of the human intelligence include:

- Multiple intelligences theory of Howard Gardner. This theory is based on studies of normal children and adults, of gifted individuals (including so-called "savants"), of persons who have suffered brain damage, of experts and virtuosos, and of individuals from diverse cultures. [7]-[10]

- Robert Sternberg proposed the triarchic theory of intelligence to provide a more comprehensive description of intellectual competence than traditional differential or cognitive theories of human ability.[11]-[17]

- Piaget's theory and Neo-Piagetian theories. In Piaget's theory of cognitive development, the focus is not on mental abilities but rather on a child's mental models of the world. As a child develops, the child creates increasingly more accurate models of the world that enable the child to interact with the world more effectively. [18]-[22].
on how progress may vary in different domains such as spatial or social.

- Parieto-frontal integration theory of intelligence. Based on a review of 37 neuroimaging studies [23]-[25]

- Investment theory. Based on the Cattell–Horn–Carroll theory, the tests of intelligence most often used in the relevant studies include measures of fluid ability (*gf*) and crystallized ability (*gc*); that differ in their trajectory of development in people [26]-[30].

- Intelligence compensation theory (ICT). The intelligence compensation theory[31]-[35]states that individuals who are comparatively less intelligent work harder and more methodically, and become more resolute and thorough (more conscientious) in order to achieve goals, to compensate for their "lack of intelligence" whereas more intelligent individuals do not require traits/behaviors associated with the personality factor conscientiousness to progress as they can rely on the strength of their cognitive abilities as opposed to structure or effort.

- Bandura's theory of self-efficacy and cognition [36]-[37]. The view of cognitive ability has evolved over the years, and it is no longer viewed as a fixed property held by an individual.

- Process, personality, intelligence and knowledge theory (PPIK)[38]-[42].

- Latent inhibition. It appears that Latent inhibition, the phenomenon of familiar stimuli having a postponed reaction time when compared with unfamiliar stimuli, has a positive correlation with creativity.

3. How 'human intelligence' is measured? What is the meaning of the IQ index? The approach to understanding intelligence with the most supporters and published research over the longest period is based on psychometric testing. It is also by far the most widely used in practical settings.[43].-[64]. There are a variety of individually administered IQ tests in use [65]-[75].While one standard deviation is 15 points, and two SDs are 30 points, and so on, this does not imply that mental ability is linearly related to IQ, such that IQ 50 would mean half the cognitive ability of IQ 100. In particular, IQ points are not percentage points.Psychometricians generally regard IQ tests as having high statistical reliability.[77][78] Reliability represents the measurement consistency of a test.[79] A reliable test produces similar scores upon repetition.[79]. Any particular estimate of IQ has an associated standard error that measures uncertainty about the estimate. For modern tests, the confidence interval can be approximately 10 points and reported standard error of measurement can be as low as about three points.[80] Reported standard error may be an underestimate, as it does not account for all sources of error.[81] Outside influences such as low motivation or high anxiety can occasionally lower a person's IQ test score.[82] For

individuals with very low scores, the 95% confidence interval may be greater than 40 points, potentially complicating the accuracy of diagnoses of intellectual disability.[83] By the same token, high IQ scores are also significantly less reliable than those near to the population median.[84] Reports of IQ scores much higher than 160 are considered dubious.[84]

Validity refers to whether the test measures what it purports to measure.[85] IQ tests are generally considered to measure some forms of intelligence, they may fail to serve as an accurate measure of broader definitions of human intelligence. For this reason, psychologist Wayne Weiten argues that their construct validity must be carefully qualified, and not be overstated.[85] According to Weiten, "IQ tests are valid measures of the kind of intelligence necessary to do well in academic work. But if the purpose is to assess intelligence in a broader sense, the validity of IQ tests is questionable." [85] Some scientists have disputed the value of IQ as a measure of intelligence altogether. In *The Mismeasure of Man* (1981, expanded edition 1996), evolutionary biologist Stephen Jay Gould compared IQ testing with the now-discredited practice of determining intelligence via craniometry, arguing that both are based on the fallacy of reification, "our tendency to convert abstract concepts into entities". [86] Gould's argument sparked a great deal of debate, [87][88] and the book is listed as one of *Discover Magazine's* "25 Greatest Science Books of All Time". [89] Along these same lines, critics such as Keith Stanovich do not dispute the capacity of IQ test scores to predict some kinds of achievement, but argue that basing a concept of intelligence on IQ test scores alone neglects other important aspects of mental ability. [77][91] Robert Sternberg, another significant critic of IQ as the main measure of human cognitive abilities, argued that reducing the concept of intelligence to the measure of g does not fully account for the different skills and knowledge types that produce success in human society. [92] Despite these objections, clinical psychologists generally regard IQ scores as having sufficient statistical validity for many clinical purposes. [90][93]

4. What means fuzzy set description of 'human intelligence'? In mathematics, fuzzy sets were first introduced by Zadeh [94] in 1965, have been applied in various field as: linguistics [95],[97],[98], [99]; control [100]-[102]; decision-making [96],[102]. Recent applications are presented in [103]-[110]

In case of an ordinary set for each object it can be decided whether it belongs or not to the set. A fuzzy set is a collection of objects without well-defined characteristics. In contrast with ordinary sets, a partial membership to a fuzzy set is possible.

The formal definition of a fuzzy set according to [94] is:

Definition 4.1. Let X be an ordinary set (called universe) A is called a fuzzy subset of X if A is a set of ordered pairs: $A = \{(x, f_A(x)); x \in X, f_A(x) \in [0, 1]\}$.

The function $f_A: X \rightarrow [0, 1]$ is called the membership function of A . The membership value $f_A(x)$ is the grade of membership of x in A . The membership value $f_A(x)$ can also be regarded as the 'true value' of the statement ' x belongs to A '. The closer $f_A(x)$ is to 1 the more x is considered to belong to A . The closer $f_A(x)$ is to 0 less x is taken to belong to A .

In some fields, especially scientific ones, there is a tendency to define sets with sharp boundaries and to accept only 'true' or 'not true' statements.

Special case of fuzzy sets are fuzzy numbers.

Definition 4.2. A fuzzy subset A of the set of real numbers R is called a fuzzy number if : there is at least one x such that $f_A(x) = 1$ (normality assumption) and for any real numbers a, b, c , with $a < b < c$ $f_A(b) > \min\{f_A(a), f_A(c)\}$.

The second property is the so-called convexity assumption, meaning that the membership function of a fuzzy number usually consists of an increasing and decreasing part, and possibly flat part.

Definition 4.3. A fuzzy subset A of the real numbers R is a triangular fuzzy number if there exists three real numbers a_1, a_2, a_3 such that $a_1 < a_2 < a_3$ and the membership function of A is given by: $f_A(x) = 0$ for $x \leq a_1$; $f_A(x) = \frac{x-a_1}{a_2-a_1}$ for $a_1 < x \leq a_2$; $f_A(x) = -\frac{x-a_3}{a_3-a_2}$ for $a_2 < x \leq a_3$; $f_A(x) = 0$ for $a_3 < x$. The support of the triangular fuzzy number is the interval (a_1, a_3) .

The use of triangular fuzzy numbers in the earthquakes intensity description is justified by the followings. Consider the measured earthquakes by the so-called body-wave technique. This technique essentially measures the amplitude of the quake as transmitted by the deep earth, rather than by the earth surface. It is known that the measuring instruments begin to saturate at about 7.00 amplitude intensity units and that by furthermore the measurements are by nature imprecise. In a fuzzy description, it is natural to take the measured value as the peak of the membership function of a fuzzy number defined on the body wave amplitude intensity scale 1 to 9. If the measured amplitude value is far enough from the saturation zone, say 6, then a symmetric triangular fuzzy number assessed subjectively from an expert may be obtained, say the support (5.8, 6.2).

A crucial point in applying fuzzy methods is the assessment of the membership functions.

A very simple way of defining a fuzzy number A with respect to a parameter x is by assessing three numbers:

1. the most credible value x^* - assigned a membership value of 1.
2. the number x^- which is almost certainly exceeded by the parameter value - assigned a membership value 0.
3. the number x^+ which is almost certainly not exceeded by the parameter value - assigned a membership value 0.

Let the membership function be defined with 0 outside of the interval (x^-, x^+) of possible values (support) and taken to be piecewise linear in between. The triangular fuzzy number $A_T = (x^-, x^*, x^+)$ has thus been constructed.

Note that the resulting membership function is not necessarily symmetrical. This represents a difference with respect to the usually accepted normally or at least symmetrically distributed error.

Other techniques are available to assess membership functions depending on the type of imprecision described by a fuzzy set.

As membership functions are often related to the perception by humans, it might be reasonable to take the human response to outside stimuli into account.

Once the membership function has been assessed, a sensitivity analysis may be performed to find out if further refinement will be necessary. If it is found that the model behavior is sensitive to the support or shape of the membership function, then it is possible to use artificial neural nets to improve an initial assessment.

The natural language expressions "human intelligence" concern a set of intellectual properties of humans and it is evaluated quantitatively with IQ index. However, the natural language expression 'human intelligence' is too vague (fuzzy) to perform computation based only on IQ index. The word intelligent may have different meanings for different persons. For example 'intelligent' for a person may mean 'very intelligent' for a second person and may mean 'more or less intelligent' for a third person. In which kind this kind of details are incorporated in IQ index is opaque, and can explain different appreciations of a person, by the members of a jury, in case of a competition. Fuzzy set model for 'human intelligence' and 'fuzzy logic' using IQ values could be a new approach which incorporates the fuzzy character of the natural language expression and transform the expression 'human intelligence' into a computationally usable form.

In order to see how this can be put in practice consider in case of the natural language expression 'human intelligence', as ordinary set X (universe) the set of the real numbers

R and the interval of real numbers $(40, 160)$. This last because for individuals with very low scores,

the 95% confidence interval may be greater than 40 IQ points, potentially complicating the accuracy of diagnoses of intellectual disability.[83] and, high IQ scores are also significantly less reliable than those near to the population median.[84] (reports of IQ scores much higher than 160 are considered dubious.[84]). Hence the idea that,

Definition 4.4. The fuzzy subset $A_{intelligent}$ corresponding to the word ‘human intelligence is the set of ordered pairs:

$$A_{intelligent} = \{(x, f_A(x)); x \in R, f_A(x) \in [0, 1]\}$$

and the membership function $f_A: R \rightarrow [0, 1]$ is the very simple function defined by :

$$f_{A_{intelligent}}(x) = 0 \text{ for } x \leq 40; f_{A_{intelligent}}(x) = \frac{x-40}{60} \text{ for } 40 < x \leq 100; f_{A_{intelligent}}(x) = -\frac{x-160}{60} \text{ for } 100 < x \leq 160; f_{A_{intelligent}}(x) = 0 \text{ for } 160 < x \quad (4.1)$$

In the above formula:

the number $x^- = 40$ which is almost certainly exceeded by the IQ index

the number $x^+ = 160$ which is almost certainly not exceeded by the IQ index

the number $x^* = 100 = \text{the most credible IQ index}$.That is because two-thirds of the population scoring between IQ index 85 and 115.

The graphic as presented in Fig.1

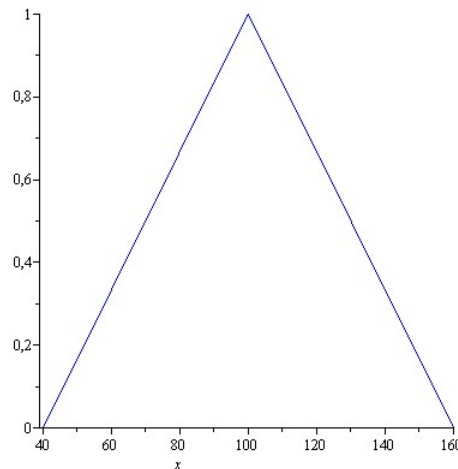


Fig.1.Fuzzy subset $A_{intelligent}$ corresponding to the fuzzy statement (x is intelligent) in WAIS scale.

The graphic describes (corresponds) the fuzzy logic statement (x is $A_{intelligent}$) and $f_{A_{intelligent}}(x)$ is ‘the true value’ or the degree of fulfillment DOF of the fuzzy logic statement (x is $A_{intelligent}$) i.e.

$$DOF(x \text{ is } A_{intelligent}) = f_{A_{intelligent}}(x).$$

Representing the natural language expression “human intelligence” with fuzzy subset $A_{intelligent}$ ambiguity in the interpretation of the IQ index is introduced. The ‘true value’= grade of membership = the number $f_{A_{intelligent}}(x = IQ) = DOF(x = IQ \text{ is } A_{intelligent})$ represent this ambiguity .

In case of a given set of IQ points, making the identification of the ‘less than intelligent persons’, the ‘intelligent persons’ and the ‘more than intelligent persons’ using only IQ points (ignoring ambiguity) it is possible to obtain

different results from that obtained using $f_{A_{intelligent}}(x = IQ)$ values. For example in the case of the set of IQ points

$$IQ := [71, 74, 53, 61, 41, 50, 65, 72, 119, 115, 119, 120, 125, 124, 125, 125, 129, 129, 123, 49, 50, 50, 47, 65, 132, 135, 153, 152, 42, 60, 80, 81, 95, 100, 105] \quad (4.2)$$

if we agree that people with IQ points less than 85 are 'less than intelligent persons, with IQ points between 85 and 115 are intelligent and people with IQ points between 115 and 160 are more than intelligent persons, the next results is obtained :

-less than intelligent persons [71, 74, 53, 61, 41, 50, 65, 72, 49, 50, 50, 47, 65, 42, 60, 80, 81] (4.3)

-intelligent persons [95, 100, 105] (4.4)

-more than intelligent persons [119, 115, 119, 120, 125, 124, 125, 125, 129, 129, 123, 132, 135, 153, 152] (4.5)

In case of this identification there are: 17 less than intelligent persons, 3 intelligent person and 15 more than intelligent persons.

The above identification use strictly IQ index and the result is unique. On the other hand according to Wayne Weiten, "IQ index is a valid measure of the kind of intelligence necessary to do well in academic work. But if the purpose is to assess intelligence in a broader sense, the validity of IQ index is questionable." [85]

For those persons who assess intelligence in a broader sense may be it is not sufficient the above classification and it is necessary the use of a second parameter, in which the ambiguity of the word 'human intelligence' is also incorporated. This second parameter can be '*the tru valu' of the statement $(x = IQ \text{ is } A_{intelligent}) = DOF(x = IQ \text{ is } A_{intelligent}) \text{ value.}$*

In case of the of IQ indexes given by (4.2) the set of the $DOF(x = IQ \text{ is } A_{intelligent})$ values can be found using computer and the membership function of the fuzzy subset $A_{intelligent}$.

The set of $DOF(x = IQ \text{ is } A_{intelligent})$ values = '*the tru valu' of the statement $(x = IQ \text{ is } A_{intelligent})$* obtained in this way is :

$$DOFIQ := [0.51666666670.56666666670.21666666670.35000000000.016666666670.16666666670.41666666670.53333333330.68333333330.75000000000.68333333330.66666666670.58333333330.60000000000.58333333330.58333333330.51666666670.51666666670.61666666670.15000000000.16666666670.16666666670.11666666670.41666666670.46666666670.41666666670.11666666670.13333333330.03333333330.33333333330.66666666670.68333333330.91666666671, 0.9166666667]$$

(4.6)

The $DOFI(IQ)$ value is the membership value ('true value') of the index IQ in case of fuzzy subset $A_{intelligent}$. If in a competition, the jury decide at the start, to reject those candidates whose $DOFI(IQ)$ values is low, for example less than 0.5 point, and accept only those candidates whose $DOFI(IQ)$ is high, more than 0.5 point, then using computer it is possible to select the set of rejected candidates and the set of accepted candidates. The obtained result in case of the set (4.2) is the following:

$$\begin{aligned} \text{-rejected candidates.} & \quad 0.21666666670.35000000000.016666666670.16666666670.41666666670.15000000000.16666666670.16666666670.11666666670.41666666670.46666666670.41666666670.11666666670.13333333330.03333333330.33333333330.66666666670.68333333330.91666666671, 0.9166666667 \\ \text{-accepted candidates.} & \quad 0.51666666670.56666666670.53333333330.68333333330.75000000000.68333333330.66666666670.58333333330.60000000000.58333333330.51666666670.51666666670.61666666670.66666666670.68333333330.91666666671, 0.9166666667 \end{aligned}$$

(4.7) (4.8)

According to this, criteria among the whole set of 35 candidates 16 persons are rejected at the start and only 19 persons are accepted to participate at the competition. The great number of candidates (16) rejected at the start show that the $DOFI(IQ)$ = 'the tru valu' of the statement ($x = IQ$ is $A_{intelligent}$) has an important influence in interpretation of the IQ index signification.

For see in detail:

-the 'less than intelligent' candidates (according to their IQ index) who are rejected because their $DOFI(IQ)$, the 'less than intelligent' candidates (according to their IQ index) who are accepted because their $DOFI(IQ)$;
-the 'intelligent' candidates' (according to their IQ index) who are rejected because their $DOFI(IQ)$, the 'intelligent' candidates (according to their IQ index) who are accepted because their $DOFI(IQ)$;
-the 'more than intelligent' candidates' (according to their IQ index) who are rejected because their $DOFI(IQ)$, the 'more than intelligent' candidates (according to their IQ index) who are accepted because their $DOFI(IQ)$;
each of the 3 groups of candidates 'less than intelligent candidate', 'intelligent candidate' and 'more than intelligent candidate' classified according to his IQ index has to be divided in two subgroups : candidates having $DOFI(IQ)$ point less than 0.5 and candidates having $DOFI(IQ)$ point more than 0.5 point .
The obtained result is the following.

The set of $DOFLI(IQ)$ of ‘less intelligent’ candidates given by (4.3) is

$$DOFLI(IQ) [0.5166666667, 0.5666666667, 0.2166666667, 0.3500000000, 0.0166666667, 0.1666666667, 0.4166666667, 0.5333333333, 0.1500000000, 0.1666666667, 0.1666666667, 0.1166666667, 0.4166666667, 0.0333333333, 0.3333333333, 0.6666666667, 0.6833333333] \quad (4.9)$$

-accepted candidates at the start from the group

$$[0.5166666667, 0.5666666667, 0.5333333333, 0.6666666667, 0.6833333333] \quad (4.10)$$

-rejected candidates at the start from the group

$$[0.2166666667, 0.3500000000, 0.0166666667, 0.1666666667, 0.4166666667, 0.1500000000, 0.1666666667, 0.1666666667, 0.1166666667, 0.4166666667, 0.0333333333, 0.3333333333] \quad (4.11)$$

In the group of less than intelligent candidates, there are 17 candidates. It is interesting to remark that 5 candidates from the group of ‘less than intelligent persons’ are accepted at the start due to their high $DOFI(IQ)$ values and 12 candidates from the group are rejected at the start because their low $DOFI(IQ)$ values.

The set of $DOFI(IQ)$ of ‘intelligent’ candidates given by (4.4) is

$$DOFI(IQ) = DOFI := [0.9166666667, 0.9166666667]; \quad (4.12)$$

-accepted candidates at the start from the group $[0.9166666667, 0.9166666667];$
(4.13)

-rejected candidates at the start from the group

$$[] \quad (4.14)$$

In the group of intelligent candidates, there are 3 candidates. All the 3 candidates from the group of ‘intelligent’ persons are accepted at the start to participate at the competition due to their high $DOFI(IQ)$ values.

The set of $DOFIMI(IQ)$ of ‘more than intelligent’ candidates given by (4.5) is

$$DOFIMI := [0.6833333333, 0.7500000000, 0.6833333333, 0.6666666667, 0.5833333333, 0.6000000000, 0.5833333333, 0.5833333333, 0.5166666667, 0.5166666667, 0.6166666667, 0.4666666667, 0.4166666667, 0.1166666667, 0.1333333333];$$

(4.15)

$$\begin{aligned} &\text{-accepted candidates at the start from the group} \\ &[0.68333333330.75000000000.68333333330.6666666667 \\ &0.58333333330.60000000000.58333333330.5833333333 \\ &0.51666666670.51666666670.6166666667] \end{aligned} \quad (4.16)$$

$$\begin{aligned} &\text{-rejected candidates at the start from the group} \\ &[0.46666666670.41666666670.11666666670.1333333333] \end{aligned} \quad (4.17)$$

In the group of ‘more than intelligent’ candidates, there are 15 candidates. Only 11 candidates were accepted at the start due to the high value of their $DOFI(IQ)$ and 4 candidates from this group was rejected at the start due to the low value of their $DOFIMI(IQ)$. This last result can be suggestive concerning the effect of the $DOFIMI(IQ)$ use in classification.

Globally from the set of 35 candidates, at the start 16 candidates were rejected because the low value of their $DOFI(IQ)$ and only 19 candidates were accepted due to the high value of their $DOFI(IQ)$.

5. What is the effect of linguistic modifiers in case of the natural languish expression ‘human intelligence’? In natural language frequently, a specification of the properties is often done using linguistic modifiers (hedges) [95]. These modifiers might both increase or decrease the uncertainty. Some of this hedge are: VERY, FAIRLY, MOSTLY, OFTEN, SOMEWHAT, INDEED, ROUGHLY, ALMOST, MORE OR LESS, SORT OFF, PRACTICALLY, NOT, MOST OFF, AT LEAST A FEW. These hedges are applied to fuzzy linguistic expression, resulting in either a more precise or imprecise vague linguistic expression.

The effect of the linguistic modifier very. Applying the linguistic modifier very to the fuzzy statement (x is intelligent), defined by (4.1), the fuzzy logic statement (x is very intelligent) is obtained. It seems that the fuzzy statement (x is very intelligent) require higher exigency in comparison with that of the fuzzy statement (x is intelligent). The membership function of the fuzzy logic statement (x is very intelligent) is the piecewise nonlinear function [95] given by:

$$f_{A_{very-intel}}(x) = f_{A_{intelligent}}^2(x) \quad (5.1)$$

The fuzzy subset $A_{very-intellige}$, representing the fuzzy logic statement (x is very intelligent) as presented in Fig.2

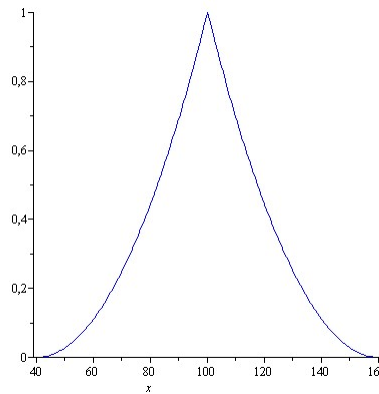


Fig.2 Fuzzy subset $A_{very-intelligent}$ representing the fuzzy statement (x is very intelligent) in WAIS scale.

A way to incorporate the ambiguity introduced by the fuzzy statement (x is very intelligent) in case of the set IQ indexes (4.2) is by adding beside IQ indexes, a second parameter, namely the $DOFVI(IQ) = DOF(x = IQ \text{ is } A_{very-intelligent})$ values = 'the true value' of the statement ($x = IQ \text{ is } A_{very-intelligent}$) points. For this purpose, the set of the $DOFVI(IQ)$ points has to be found using computer and the membership function of the fuzzy subset $A_{very-intelligence}$.

The set of $DOFVI(IQ)$ points obtained in this way is:

(5.2)

$$\begin{aligned} DOFVI IQ := & [0.2669444444, 0.3211111111, 0.0469444444, \\ & 0.1225000000, 0.000277777778, 0.0277777778, 0.1736111111, \\ & 0.2844444444, 0.4669444444, 0.5625000000, 0.4669444444, \\ & 0.4444444444, 0.3402777778, 0.3600000000, 0.3402777778, \\ & 0.3402777778, 0.2669444444, 0.2669444444, 0.3802777778, \\ & 0.0225000000, 0.0277777778, 0.0277777778, 0.0136111111, \\ & 0.1736111111, 0.2177777778, 0.1736111111, 0.0136111111, \\ & 0.0177777778, 0.0011111111, 0.0011111111, 0.4444444444, \\ & 0.4669444444, 0.8402777778, 1, 0.8402777778] \end{aligned}$$

The $DOFVI(IQ)$ value is the membership value ('true value') of the IQ index in case of fuzzy subset $A_{very-intelligent}$. If in a competition, the jury decide at the start, to reject those candidates whose $DOFVI(IQ)$ values is low, for example less than 0.5 point, and accept only those candidates whose $DOFVI(IQ)$ is high, more than 0.5 point, then using computer it is possible to select the set of rejected candidates and the set of accepted candidates. The obtained result in case of the set (4.2) is the following :

-rejected candidates.

0.26694444440.32111111110.04694444440.1225000000
0.0002777777780.027777777780.17361111110.2844444444
0.46694444440.46694444440.44444444440.3402777778
0.36000000000.34027777780.34027777780.2669444444
0.26694444440.38027777780.02250000000.0277777778
0.02777777780.01361111110.17361111110.2177777778
0.17361111110.01361111110.01777777780.00111111111
0.001111111110.44444444440.4669444444

(5.3)

-accepted candidates. [0.56250000000.84027777781, 0.8402777778]
(5.4)

According to this, criteria among the whole set of 35 candidates, 31 candidates are rejected at the start and only 4 candidates are accepted for participate at competition.

For see in detail:

-who are the 'less than very intelligent' candidates rejected because their low $DOFVI(IQ)$ values, and who are the 'less than very intelligent candidates' accepted because their high $DOFVI(IQ)$ values ;
-who are the 'very intelligent candidates' rejected because their low $DOFVI(IQ)$ values ,and who are the ' very intelligent candidates' accepted because their high $DOFVI(IQ)$ values ;
- who are the ' more than very intelligent' candidates rejected because their low $DOFVI(IQ)$ values ,and who are the 'more than very intelligent candidates' accepted because their high $DOFVI(IQ)$
each of the groups of candidates 'less than very intelligent person' , 'very intelligent person' and 'more than very intelligent person', classified according to IQ points, has to be divided in two subgroups : persons having $DOFVI(IQ)$ values less than 0.5 and candidates having $DOFVI(IQ)$ values more than 0.5 point .

The $DOFVI(IQ)$ of the 'less than very intelligent' candidates is the following:

$DOFVI := [0.2669444444, 0.3211111111, 0.0469444444, 0.1225000000, 0.000277777778, 0.0277777778, 0.1736111111, 0.2844444444, 0.0225000000, 0.0277777778, 0.0277777778, 0.0136111111, 0.1736111111, 0.0011111111, 0.1111111111, 0.4444444444, 0.4669444444];$ (5.5)

-accepted candidates at the start from the group

[]

-rejected candidates at the start from the group

0.26694444440.32111111110.04694444440.1225000000 (5.6)
0.0002777777780.02777777780.17361111110.2844444444
0.02250000000.02777777780.02777777780.0136111111
0.17361111110.00111111110.11111111110.4444444444
0.4669444444

In the group of 'less than very intelligent' candidates, there are 17 candidates. All the 17 candidates are rejected at the start because of their low $DOFVI(IQ)$ values.

The $DOFVI(IQ)$ of the 'very intelligent' candidates is the following:

$$DOFVI := [0.8402777778, 0.8402777778] \quad (5.7)$$

- accepted candidates at the start from the group

$$[0.8402777778, 0.8402777778]$$

-rejected candidates at the start from the group

$$[] \quad (5.8)$$

In the group of ‘very intelligent’ candidates, there are 3 candidates. All the 3 candidates are accepted at the start because of their high $DOFVI(IQ)$ values.

The $DOFVI(IQ)$ of the ‘more than very intelligent’ candidates is the following:

$$DOFMVI := [0.4669444444, 0.5625000000, 0.4669444444, \quad (5.9)$$

$$0.4444444444, 0.3402777778, 0.3600000000, 0.3402777778,$$

$$0.3402777778, 0.2669444444, 0.2669444444, 0.3802777778,$$

$$0.2177777778, 0.1736111111, 0.0136111111, 0.0177777778];$$

-accepted candidates at the start from the group

$$[0.5625000000] \quad (5.10)$$

-rejected candidates at the start from the group

$$[0.4669444444, 0.4669444444, 0.4444444444, 0.3402777778, \quad (5.11)$$

$$0.3600000000, 0.3402777778, 0.3402777778, 0.2669444444,$$

$$0.2669444444, 0.3802777778, 0.2177777778, 0.1736111111,$$

$$0.0136111111, 0.0177777778]$$

In the group of ‘more than very intelligent’ candidates, there are 15 candidates. 14 candidates are rejected at the start because of their low $DOFVI(IQ)$ values. Just one of the candidates is accepted due to its high $DOFVI(IQ)$ value.

In the interpretation of the fuzzy concept ‘very intelligent’ globally from the set of 35 candidates, at the start 31 candidates were rejected because the low value of their $DOFVI(IQ)$ and only 4 candidates were accepted due to the high value of their $DOFVI(IQ)$.

Comparing the rejected number 31, with the rejected number 16 obtained in the interpretation of the fuzzy concept 'intelligent', it is obvious that the exigency behind the fuzzy concept 'very intelligent' is higher than the exigency behind the fuzzy concept 'intelligent'

The effect of the linguistic modifier MORE OR LESS. Applying to the fuzzy logic statement (x is intelligent), defined by (4.1), the linguistic modifier more or less the fuzzy logic statement (x is more or less intelligent) is obtained. It seems that the fuzzy statement (x is more or less intelligent) less exigent than the fuzzy statement (x is intelligent). The membership function of the fuzzy logic statement (x is more or less intelligent) is the piecewise nonlinear function [95] given by:

$$f_{A_{\text{more or less intelligent}}}(x) = \sqrt{f_{A_{\text{intelligent}}}(x)} \quad (5.12)$$

The graphic of computed fuzzy subset $A_{\text{more or less intelligent}}$ representing the fuzzy logic statement (x is more or less intelligent), as presented in Fig.3

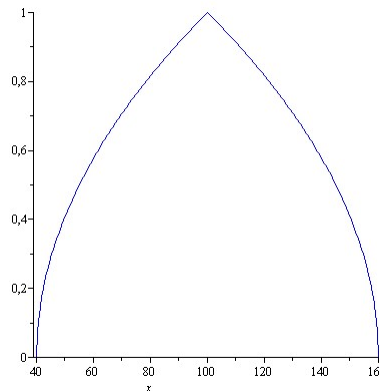


Fig.3 Graphic of the fuzzy subset $A_{\text{more or less intelligent}}$ representing the fuzzy statement (x is more or less intelligent) in WAIS scale.

A way to incorporate the ambiguity introduced by the fuzzy statement (x is more or less intelligent) in case of IQ indexes (4.2) is by adding beside IQ indexes, a second parameter, namely the $DOFMLI(IQ) = DOF(x = IQ \text{ is } A_{\text{more or less intelligent}})$ value = 'the true value' of the statement ($x = IQ$ is $A_{\text{more or less intelligent}}$) points.

For this purpose, the set of the $DOFMLI(IQ)$ points has to be found using computer and the membership function of the fuzzy subset $A_{\text{more or less intelligent}}$.

The set of $DOFMLI(IQ)$ points obtained in this way is:

$DOFMLIQ := [0.7187952883, 0.7527726526, 0.4654746680,$
 $0.5916079783, 0.1290994449, 0.4082482906, 0.6454972245,$
 $0.7302967432, 0.8266397846, 0.8660254040, 0.8266397846,$
 $0.8164965809, 0.7637626160, 0.7745966692, 0.7637626160,$
 $0.7637626160, 0.7187952883, 0.7187952883, 0.7852812659,$
 $0.3872983346, 0.4082482906, 0.4082482906, 0.3415650256,$
 $0.6454972245, 0.6831300514, 0.6454972245, 0.3415650256,$
 $0.3651483717, 0.1825741858, 0.1825741858, 0.8164965809,$
 $0.8266397846, 0.9574271080, 1, 0.9574271080];$

(5.13)

The $DOFMLI(IQ)$ value is the membership value ('true value') of the IQ index in case of fuzzy subset $A_{more\ or\ less\ intelligent}$. If in a competition, the jury decide at the start, to reject those candidates whose $DOFMLI(IQ)$ values is low, for example less than 0.5 point, and accept only those candidates whose $DOFMLI(IQ)$ is high, more than 0.5 point, then using computer it is possible to select the set of rejected candidates and the set of accepted candidates at the start. The obtained result in case of the set (4.2) is the following:

-rejected candidates $[0.4654746680, 0.1290994449, 0.4082482906, 0.3872983346,$
 $0.4082482906, 0.4082482906, 0.3415650256, 0.3415650256,$
 $0.3651483717, 0.1825741858, 0.1825741858]$

(5.14)

-accepted candidates $0.7187952883, 0.7527726526, 0.5916079783, 0.6454972245,$
 $0.7302967432, 0.8266397846, 0.8660254040, 0.8266397846,$
 $0.8164965809, 0.7637626160, 0.7745966692, 0.7637626160,$
 $0.7637626160, 0.7187952883, 0.7187952883, 0.7852812659,$
 $0.6454972245, 0.6831300514, 0.6454972245, 0.8164965809,$
 $0.8266397846, 0.9574271080, 1, 0.9574271080]$

(5.15)

According to this, criteria among the whole set of 35 candidates, 11 candidates are rejected at the start, because their $DOFMLI(IQ)$ point is low, and only 24 candidates are accepted for participate at competition, because their $DOFMLI(IQ)$ point is sufficiently high.

More refined analysis can be made computing the rejected or the accepted candidates at the levels: 'less than more or less intelligent', 'more or less intelligent' and 'more than more or less intelligent'. The algorithm is similar with that presented in previous examples.

Applying the linguistic modifier INDEED to the fuzzy logic statement (x is intelligent) defined by (4.1) the fuzzy logic statement (x is indeed intelligent) is obtained. Apparently the exigency of fuzzy statement (x is indeed intelligent) is more than the exigency of fuzzy statement (x is intelligent). The membership function of the fuzzy logic statement (x is indeed intelligent) is the piecewise nonlinear function [95] given by:

$$f_{A_{indeed\ intelligent}}(x) = 2 \times f_{A_{intelligent}}^2(x) \text{ for } f_{A_{intelligent}}(x) \leq 0.5 \text{ and } f_{A_{indeed\ intelligent}}(x) = 1 - 2 \times (1 - f_{A_{intelligent}}(x))^2 \text{ for } 0.5 < f_{A_{intelligent}}(x) \quad (5.16)$$

The graphic of the computed fuzzy subset $A_{indeed\ intelligent}$ representing the fuzzy logic statement (x is indeed intelligent), as presented in Fig.4

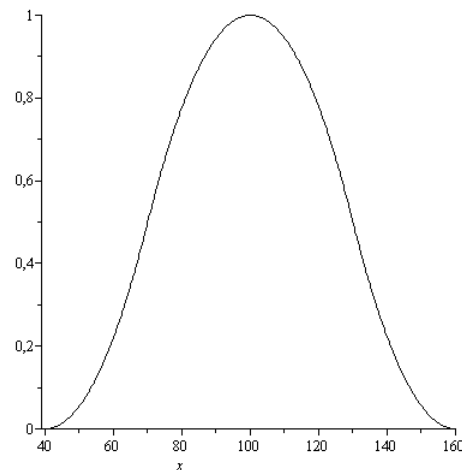


Fig.4 Graphic of the fuzzy subset $A_{indeed\ intelligent}$ representing the fuzzy statement (x is indeed intelligent in WAIS scale.

A way to incorporate the ambiguity introduced by the fuzzy statement (x is indeed intelligent, in case of IQ indexes (4.2), is by adding beside IQ indexes, a second parameter, namely the $DOFII(IQ) = DOF(x = IQ \text{ is } A_{indeed\ intelligent})$ value = 'the true value' of the statement ($x = IQ \text{ is } A_{indeed\ intelligent}$) points. For this purpose, the set of the $DOFII(IQ)$ points has to be found using computer and the membership function of the fuzzy subset $A_{indeed\ intelligent}$.

The set of $DOFII(IQ)$ points obtained in this way is:

(5.17)

$$DOFIIIQ := [0.5327777778, 0.6244444444, 0.09388888889, 0.2450000000, 0.0005555555556, 0.05555555556, 0.3472222222, 0.5644444444, 0.7994444444, 0.5625000000, 0.4669444444, 0.7777777778, 0.6527777778, 0.6800000000, 0.6527777778, 0.3402777778, 0.5327777778, 0.5327777778, 0.3802777778, 0.0450000000, 0.05555555556, 0.05555555556, 0.0272222222, 0.3472222222, 0.4311111111, 0.3194444444, 0.0272222222, 0.03555555556, 0.00222222222, 0.00222222222, 0.7777777778, 0.7994444444, 0.9861111111, 1, 0.9861111111];$$

The $DOFII(IQ)$ value is the membership value ('true value') of the IQ index in case of fuzzy subset $A_{indeed\ intelligent}$. If in a competition, the jury decide at the start, to reject those candidates whose $DOFII(IQ)$ values is low, for example less than 0.5 point, and accept only those candidates whose $DOFII(IQ)$ is high, more than 0.5 point, then using computer it is possible to select the set of rejected candidates and the set of accepted candidates at the start. The obtained result in case of the set (4.2) is the following:

-rejected candidates 0.09388888890.24500000000.000555555555560.055555555556
0.34722222220.46694444440.34027777780.3802777778
0.045000000000.0555555555560.0555555555560.02722222222
0.34722222220.43111111110.31944444440.02722222222
0.0355555555560.002222222220.00222222222

(5.18)

-accepted candidates [0.53277777780.62444444440.56444444440.7994444444
0.56250000000.77777777780.65277777780.6800000000
0.65277777780.53277777780.53277777780.7777777778
0.79944444440.98611111111, 0.9861111111]

(5.19)

According to this, criteria among the whole set of 35 candidates, 19 candidates are rejected at the start, because their $DOFII(IQ)$ point is low, and only 16 candidates are accepted for participate at competition, because their $DOFII(IQ)$ point is sufficiently high.

More refined analysis can be made computing the rejected or the accepted candidates at the levels: 'less than more or less intelligent', 'more or less intelligent' and 'more than more or less intelligent'. The algorithm is similar with that presented in previous examples.

A rough representation of the difference between the fuzzy subsets

$A_{intelligent}$, $A_{very\ intelligent}$, $A_{more\ or\ less\ intelligent}$, $A_{indeed\ intelligent}$ corresponding to the fuzzy logic statements $(x\ is\ intelligent)$, $(x\ is\ very\ intelligent)$, $(x\ is\ more\ or\ less\ intelligent)$, $(x\ is\ indeed\ intelligent)$ respectively can be seen in figure 5 where $A_{intelligent}$, $A_{very\ intelligent}$, $A_{more\ or\ less\ intelligent}$, $A_{indeed\ intelligent}$ are represented with colors red, blue, green and black respectively.

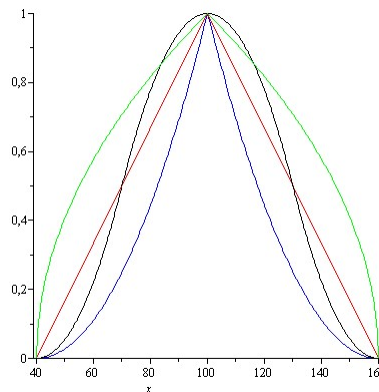


Fig.5 Fuzzy sets corresponding to the fuzzy logic statements: $(x\ is\ intelligent)$ color red; $(x\ is\ very\ intelligent)$ color blue; $(x\ is\ more\ or\ less\ intelligent)$ color green, $(x\ is\ indeed\ intelligent)$ color black.

It can be seen that:

- in case of the fuzzy logic statement (*x is very intelligent*) the membership value of all the uncertain elements is less than in case of the fuzzy logic statement (*x is intelligent*);

-in case of the fuzzy logic statement (*x is more or less intelligent*) the membership of all the uncertain elements is more than in the case of the fuzzy logic statement (*x is intelligent*);

-in case of the fuzzy logic statement (*x is indeed intelligent*) the membership value of uncertain elements x for which $DOFI(x \text{ is } A_{\text{intelligent}}) \leq 0.5$ implies $DOFI(x \text{ is } A_{\text{indeed intelligent}}) \leq DOFI(x \text{ is } A_{\text{intelligent}}) \leq 0.5$ and for those x for which $DOFI(x \text{ is } A_{\text{intelligent}}) > 0.5$ inequality $DOFI(x \text{ is } A_{\text{indeed intelligent}}) > DOFI(x \text{ is } A_{\text{intelligent}})$.

Mathematically these differences are generated by the choice of interpolation of the values 0 at $x^- = 40$; 1 at $x^* = 100$; and 0 at $x^+ = 160$. In case of $A_{\text{intelligent}}$ the interpolation is piecewise linear; in case of $A_{\text{very intelligent}}$, $A_{\text{more or less intelligent}}$ and $A_{\text{indeed intelligent}}$ is nonlinear.

If $A_{\text{intelligent}}$ describes the understanding of general intelligence then $A_{\text{very intelligent}}$ describes a more exigent understanding of the general intelligence; $A_{\text{more or less intelligent}}$ describes a less exigent understanding of the general intelligence; $A_{\text{indeed intelligent}}$ represent a more exigent understanding of the general intelligence for the IQ values in the intervals [40, 70] and [130, 160] and $A_{\text{indeed intelligent}}$ represent a less exigent understanding of the general intelligence for the IQ values in the interval [70, 130].

6. What is the linguistic variable ‘HUMAN INTELLIGENCE’?

The formal definition of a linguistic variable Y is :

Definition.6.1.

Y is a 4 – tuple $Y = (T, X, G, M)$ where:

T is a set of natural language terms from which t can take on its values, X is a univers , on which the fuzzy set corresponding to the linguistic variable are defined, G is a context free grammar used to generate the elements of F , $M: T \rightarrow F$ [97].

Linguistic variables make the natural language computation possible [97].

Sometimes there is no set X that can be naturally associated to the linguistic expression. That is because there is no measure for them. Consider for example the linguistic expression; good, pain, happy, joy, excellent, acceptable, etc.

Definition.6.2.

Following definition 6.1. we take the natural language term ‘intelligent’ adding the terms obtained with the 14 linguistic modifiers obtaining a set T of 15 natural language terms $T = \{ \text{‘intelligent’}, \text{‘very intelligent’}, \dots \}$. For universe X we take the set of real numbers. The elements of the set F are the fuzzy subsets $A_{\text{intelligent}}, A_{\text{very intelligent}}, A_{\text{more or less intelligent}}, A_{\text{indeed intelligent}}, \text{etc}$ $F = \{ A_{\text{intelligent}}, A_{\text{very intelligent}}, A_{\text{more or less intelligent}}, A_{\text{indeed intelligent}}, \dots \}$ corresponding to the elements of T and M is the mapping from the set T to the set F which associate to the elements of T the

corresponding fuzzy subset from F . In this way the kernel of a linguistic variable is obtained what we will call ‘human intelligence’ linguistic variable.

In the next section, this kernel of the ‘human intelligence’ linguistic variable, which contains 15 elements, is expanded. This means that the sets T and F are expanded. The new terms which are added to T are generated by the fuzzy logic operators while the new fuzzy subsets added to the set F are the fuzzy subsets corresponding to the new terms added to T .

7. Extension of the kernel of ‘human intelligence’ linguistic variable by using fuzzy logic and fuzzy logic operators. [105]

In classic logic, a statement is true or false. For this reason in Boolean mathematical logic two values 0 (false) and 1 (true) are assigned to any statement. In the following table, the true values are given in case of the application of different logical operators.

| A | B | $\text{not } A$ | $A(AND) B$ | $A(OR) B$ | $A(XOR) B$ | $A(imply B)$ |
|-----|-----|-----------------|------------|-----------|------------|--------------|
| 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 |

Table1

where XOR stands for “either..., or,...”

In fuzzy logic no explicit functional form is assumed, binary logic is replaced by fuzzy logic where a statement and its opposite may both be “true” to a certain degree. For example, “severe” and “moderate” pathology may be both be “true” for a given patient. For fuzzy statements A, B the “true value” can vary between 0 and 1. The Boolean table has to be extended to cope with such situations in a plausible manner.

The fuzzy logic operator NOT . [105] In the fuzzy logic, the fuzzy statement (x is A) by the fuzzy logic operator NOT ,is transformed in the fuzzy logic statement (x is not A).The new fuzzy statement usually is denoted by $NOT(x$ is $A)$ or $(x$ is not $A)$. The fuzzy statement (x is not A) is represented by the fuzzy subset usually denoted by $C = A^c$ and called the fuzzy complement of A . The membership function f_C of the fuzzy subset C representing the fuzzy statement (x is not A) is by definition

$$f_C(x) = 1 - f_A(x) \quad (7.1)$$

Notation f_{NOTA} for the fuzzy complement of A is also usual.

It can be seen that the following equalities hold:

$$DOF[NOT(x is A)] = f_{NOTA}(x) = 1 - f_A(x) = f_c(x)$$

Starting with the fuzzy logic statement (*x is intelligent*) and its representation by the fuzzy subset $A_{intelligent}$, then using the fuzzy logic operator *NOT* the fuzzy logic statement (*x is not intelligent*) and its fuzzy set representative, the fuzzy complement of $A_{intelligent}$ can be constructed.

Namely the fuzzy subset $C_{not\ intelligent} = A_{intelligent}^c$.

In this way the existing kernel of the human intelligence linguistic variable can be expanded with the new linguistic expression *not intelligent*, and the corresponding fuzzy subset $A_{intelligent}^c$

The fuzzy subset $A_{intelligent}^c$ as presented in Fig.6

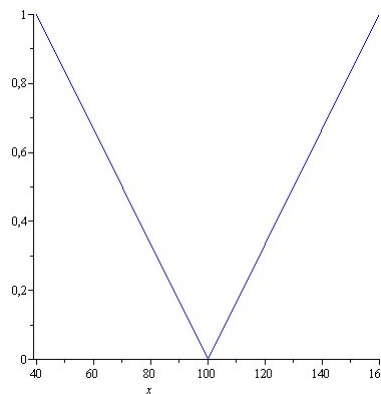


Fig.6 Fuzzy subset $A_{intelligent}^c$ representing the linguistic expression *not intelligent*.

The above-described procedure can be repeated for all elements of the kernel of human intelligence linguistic variable.

The fuzzy subsets $A_{very\ intelligent}^c$, $A_{more\ or\ less\ intelligent}^c$, $A_{indeed\ intelligent}^c$ are represented in the figures 7-9:

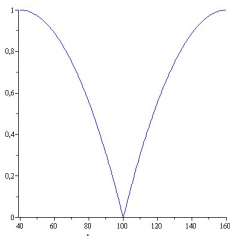


Fig. 7. $A_{very\ intelligent}^c$

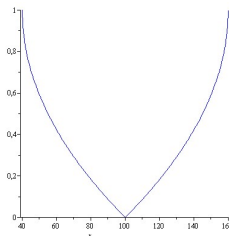


Fig. 8 $A_{more\ or\ less\ intelligent}^c$

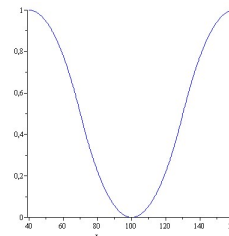


Fig. 9 $A_{indeed\ intelligent}^c$

In this way the existing kernel of the human intelligence linguistic variable having 15 elements is expanded with other 15 new elements.

The fuzzy logic operator AND. According to [105] in fuzzy logic two type of **AND** fuzzy logic operator are used: the so called ‘minimum fuzzy logic operator **AND**’ and the so called ‘product fuzzy logic operator **AND**’.

The ‘minimum fuzzy logic operator AND’ .[105] In case of two fuzzy statements $(x \text{ is } A_1), (x \text{ is } A_2)$ _the ‘minimum fuzzy logic operator **AND**’ transform these statements in the fuzzy statement $(x \text{ is } A_1) \text{ AND } (x \text{ is } A_2)$ denoted usually by ‘ $\text{minimum}(x \text{ is } A_1) \text{ AND } (x \text{ is } A_2)$ ’ The fuzzy statement ‘ $\text{minimum}(x \text{ is } A_1) \text{ AND } (x \text{ is } A_2)$ ’ is described by the fuzzy subset $C_{\text{minimum intersection}}$ which membership function is

$$f_{C_{\text{minimum intersection}}}(x) = \text{minimum}\{f_{A_1}(x), f_{A_2}(x)\} \quad (7.2)$$

This fuzzy subset usually is denoted by $C_{\text{minimum intersection}} = \text{minimum}(A_1 \cap A_2)$ and is called the “minimum fuzzy intersection” of fuzzy subsets A_1 and A_2 .

According to this definition and Fig.5 is easy to see that the ‘minimum fuzzy intersection’ for some of the elements of the ‘human intelligence linguistic variable’ the following equalities hold:

$\text{minimum}(A_{\text{intelligent}} \cap A_{\text{very intelligent}}) = A_{\text{very intelligent}}$; $\text{minimum}(A_{\text{intelligent}} \cap A_{\text{more or less intelligent}}) = A_{\text{intelligent}}$; $\text{minimum}(A_{\text{very intelligent}} \cap A_{\text{more or less intelligent}}) = A_{\text{very intelligent}}$; $\text{minimum}(A_{\text{very intelligent}} \cap A_{\text{indeed intelligent}}) = A_{\text{very intelligent}}$ However, in general the “minimum fuzzy intersection” for other elements of the ‘human intelligence linguistic variable’ require a more complex computation of the membership function.

For example in case of the minimum intersection, $\text{minimum}(A_{\text{intelligent}} \cap A_{\text{intelligent}}^c)$ the following membership function is found:

$$f_{\text{minimum}(A_{\text{intelligent}} \cap A_{\text{intelligent}}^c)}(x) = 0 \text{ for } x \leq 40 ; f_{\text{minimum}(A_{\text{intelligent}} \cap A_{\text{intelligent}}^c)}(x) = \frac{x-40}{60} \text{ for } 40 < x \leq 70 ;$$

$$f_{\text{minimum}(A_{\text{intelligent}} \cap A_{\text{intelligent}}^c)}(x) = 1 - \frac{x-40}{60} \text{ for } 70 < x \leq 100 ; f_{\text{minimum}(A_{\text{intelligent}} \cap A_{\text{intelligent}}^c)}(x) = 1 - \frac{160-x}{60} \text{ for } 100 < x \leq 130 ;$$

$$f_{\text{minimum}(A_{\text{intelligent}} \cap A_{\text{intelligent}}^c)}(x) = \frac{160-x}{60} \text{ for } 130 < x \leq 160 ; f_{\text{minimum}(A_{\text{intelligent}} \cap A_{\text{intelligent}}^c)}(x) = 0 \text{ for } 160 < x .$$

The fuzzy subset $\text{minimum}(A_{\text{intelligent}} \cap A_{\text{intelligent}}^c)$ as presented in Fig.10

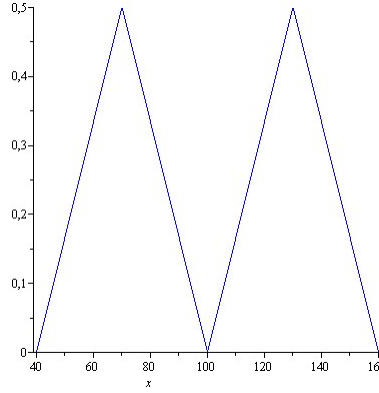


Fig.10 Fuzzy subset *minimum intersection*($A_{intelligent} \cap A_{intelligent}^c$)

We emphasize that

$$DOF[(x \text{ is } \textit{minimum}(A_{intelligent} \cap A_{intelligent}^c))] = f_{\textit{minimum}(A_{intelligent} \cap A_{intelligent}^c)}(x)$$

for $x = 70$ and $x = 130$ is equal to 0.50. This situation is similar with that already mentioned : “severe” and “moderate” pathology may be both be “true” for a given patient.

Representing the fuzzy statement

'intelligent and non intelligent' with the fuzzy subset *minimum*($A_{intelligent} \cap A_{intelligent}^c$) permits the introduction of the fuzzy statement *'intelligent and non intelligent'* together with the fuzzy subset *minimum*($A_{intelligent} \cap A_{intelligent}^c$) as a novel element of the human intelligence linguistic variable. According to this new linguistic variable the $DOF[(x \text{ is } \textit{minimum}(A_{intelligent} \cap A_{intelligent}^c))]$ is less or is equal than 0.5 for every IQ index from the data set (4.2).

In case of the minimum intersection, *minimum*($A_{intelligent} \cap A_{indeed \text{ intelligent}}$) the following membership function is found (Also, see Fig. 11):

$$f_{\textit{minimum}(A_{intelligent} \cap A_{indeed \text{ intelligent}})}(x) = 0 \text{ for } x \leq 40 ; f_{\textit{minimum}(A_{intelligent} \cap A_{indeed \text{ intelligent}})}(x) = 2 \times \left(\frac{x-40}{60}\right)^2 \text{ for } 40 < x \leq 70$$

$$f_{\textit{minimum}(A_{intelligent} \cap A_{indeed \text{ intelligent}})}(x) = \frac{100-x}{60} \text{ for } 70 < x \leq 100 ;$$

$$f_{\textit{minimum}(A_{intelligent} \cap A_{indeed \text{ intelligent}})}(x) = \frac{x-100}{60} \text{ for } 100 < x \leq 130$$

$$f_{\textit{minimum}(A_{intelligent} \cap A_{indeed \text{ intelligent}})}(x) = 2 \times \left(\frac{160-x}{60}\right)^2 \text{ for } 130 < x \leq 160 ;$$

$$f_{\textit{minimum}(A_{intelligent} \cap A_{indeed \text{ intelligent}})}(x) = 0 \text{ for } 160 < x$$

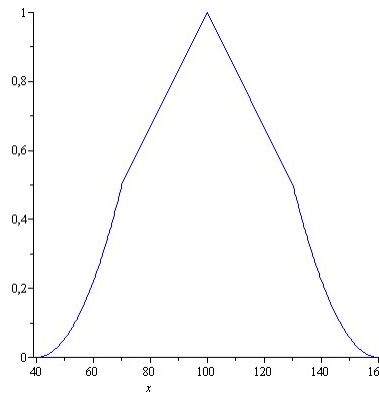


Fig.11 Fuzzy subset, $\text{minimum intersection}(A_{\text{intelligent}} \cap A_{\text{indeed intelligent}})$

We emphasize that

$$\text{DOF}[(x \text{ is } \text{minimum}(A_{\text{intelligent}} \cap A_{\text{indeed intelligent}}))] = f_{\text{minimum}(A_{\text{intelligent}} \cap A_{\text{indeed intelligent}})}(x)$$

Representing the fuzzy statement

'*intelligent and indeed intelligent*' with the fuzzy subset $\text{minimum}(A_{\text{intelligent}} \cap A_{\text{indeed intelligent}})$

a novel element of the human intelligence linguistic variable , is constructed .

Product fuzzy logic operator AND .[105] The '**product fuzzy logic operator AND**' transform two fuzzy statements $(x \text{ is } A_1)$, $(x \text{ is } A_2)$ in the fuzzy statement $(x \text{ is } A_1) \text{ AND } (x \text{ is } A_2)$ denoted usually by ' $\text{product}(x \text{ is } A_1) \text{ AND } (x \text{ is } A_2)$ '. The fuzzy statement ' $\text{product}(x \text{ is } A_1) \text{ AND } (x \text{ is } A_2)$ ' is described by the fuzzy subset $C_{\text{product intersection}}$ which membership function is

$$f_{C_{\text{product intersection}}}(x) = f_{A_1}(x) \times f_{A_2}(x) \quad (7.3)$$

This fuzzy subset usually is denoted by $C_{\text{product intersection}} = \text{product}(A_1 \cap A_2)$ and is called the 'product fuzzy intersection' of fuzzy subsets A_1 and A_2 .

In general the 'product fuzzy intersection' for the elements of the 'human intelligence linguistic variable' require the computation of the membership function using (7.3)

For example if A_1 is the fuzzy subset $A_{\text{intelligent}}$ and A_2 is the fuzzy subset $A_{\text{very intelligent}}$ then their "prod fuzzy intersection" computed with (7.3) as presented in Fig.12

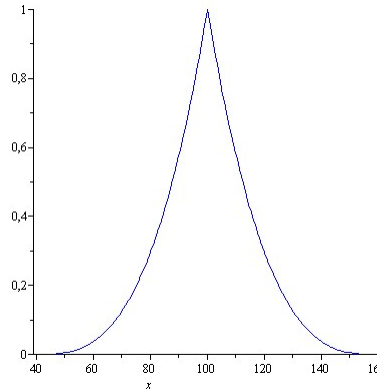


Fig.12 Fuzzy subset, *product intersection*($A_{intelligent} \cap A_{very\ intelligent}$)

Representing the fuzzy statement

'*intelligent and very intelligent*' with the fuzzy subset *product*($A_{intelligent} \cap A_{very\ intelligent}$) a novel element of the human intelligence linguistic variable, is constructed.

We emphasize that $DOF[(x \text{ is } product(A_{intelligent} \cap A_{very\ intelligent})) = f_{A_{intelligent}}(x) \times f_{A_{very\ intelligent}}(x)$

Fuzzy logic operator OR. According to [105] in fuzzy logic, two type of fuzzy logic operator **OR** are used: the so called 'maximum fuzzy logic operator **OR**' and a so called 'product fuzzy logic operator **OR**'

Maximum fuzzy logic operator OR. [105] The 'maximum fuzzy logic operator **OR**' transforms two fuzzy statements ($x \text{ is } A_1$), ($x \text{ is } A_2$) in the fuzzy statement

($x \text{ is } A_1$)**OR**, ($x \text{ is } A_2$) denoted usually with '*maximum*($x \text{ is } A_1$)**OR**($x \text{ is } A_2$)'. The fuzzy statement '*maximum*($x \text{ is } A_1$)**AND**($x \text{ is } A_2$)' is described by the fuzzy subset

$C_{maximum\ union}$ which membership function is

$$f_{C_{maximum\ union}}(x) = maximum\{f_{A_1}(x), f_{A_2}(x)\} \quad (7.4)$$

This fuzzy subset usually is denoted by $C_{maximum\ union} = maximum(A_1 \cup A_2)$ and is called the 'maximum fuzzy union' of fuzzy subsets A_1 and A_2 .

In general the 'maximum fuzzy union' for the elements of the 'human intelligence linguistic variable' require the computation of the membership function using (7.4)

For example if A_1 is the fuzzy subset $A_{intelligent}$ and A_2 is the fuzzy subset $A_{indeed\ intelligent}$ then their "maximum fuzzy union" computed with (7.4) as presented in Fig.13

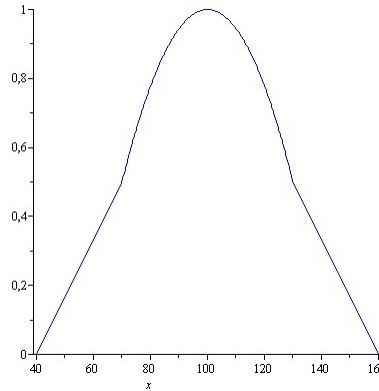


Fig.13 $\text{maximum union}(A_{\text{intelligent}} \cup A_{\text{indeed intelligent}})$

Representing the fuzzy statement

'*intelligent or indeed intelligent*' with the fuzzy subset $\text{maximum}(A_{\text{intelligent}} \cup A_{\text{indeed intelligent}})$ a novel element of the human intelligence linguistic variable, is constructed.

We emphasize that $\text{DOF}[(x \text{ is } \text{maximum}(A_{\text{intelligent}} \cup A_{\text{indeed intelligent}})) = \text{maximum}\{f_{A_{\text{intelligent}}}(x), f_{A_{\text{indeed intelligent}}}(x)\}$.

Product fuzzy logic operator. [105] The 'product fuzzy logic operator **OR**' transforms two fuzzy statements $(x \text{ is } A_1), (x \text{ is } A_2)$ in the fuzzy statement

$(x \text{ is } A_1) \text{OR}, (x \text{ is } A_2)$ denoted usually with ' $\text{product}(x \text{ is } A_1) \text{OR}(x \text{ is } A_2)$ '. The fuzzy statement

' $\text{product}(x \text{ is } A_1) \text{OR}(x \text{ is } A_2)$ ' is described by the fuzzy subset $C_{\text{product union}}$ which membership function is

$$f_{C_{\text{product union}}}(x) = f_{A_1}(x) + f_{A_2}(x) - f_{A_1}(x) \times f_{A_2}(x) \quad (7.5)$$

This fuzzy subset usually is denoted by $C_{\text{product union}} = \text{product}(A_1 \cup A_2)$ and is called the 'product fuzzy union' of fuzzy subsets A_1 and A_2 .

In general, the 'product fuzzy union' for the elements of the 'human intelligence linguistic variable' require the computation of the membership function using (7.5)

For example if A_1 is the fuzzy subset $A_{\text{intelligent}}$ and A_2 is the fuzzy subset $A_{\text{indeed intelligent}}$ then their "maximum fuzzy union" computed with (7.5) as presented in Fig.14

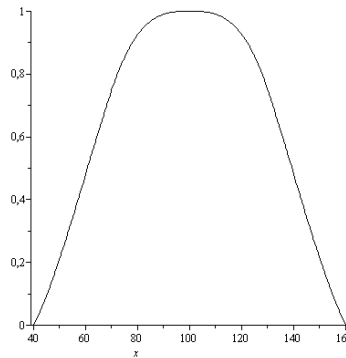


Fig.14 Fuzzy subset ' $product\ union(A_{intelligent} \cup A_{indeed\ intelligent})$ '

Representing the fuzzy statement

'*intelligent or indeed intelligent*' with the fuzzy subset *product union* ($A_{intelligent} \cup A_{indeed\ intelligent}$) a novel element of the human intelligence linguistic variable, is constructed.

We emphasize that $DOF[(x\ is\ product\ union(A_{intelligent} \cup A_{indeed\ intelligent})) = f_{A_{intelligent}}(x) + f_{A_{indeed\ intelligent}}(x) - f_{A_{intelligent}}(x) \times f_{A_{indeed\ intelligent}}(x)$.

Fuzzy logic operator XOR. According to [105] in fuzzy logic, two kind of XOR operator are used the so called 'product fuzzy logic operator XOR' and a so called 'min-max fuzzy logic operator XOR'.

Product fuzzy logic operator XOR. [105] The 'product fuzzy logic operator XOR' transforms two fuzzy statements ($x\ is\ A_1$), ($x\ is\ A_2$) in the fuzzy statement

$(x\ is\ A_1)XOR, (x\ is\ A_2)$ denoted usually with ' $product(x\ is\ A_1)XOR(x\ is\ A_2)$ '. The fuzzy statement ' $product(x\ is\ A_1)XOR(x\ is\ A_2)$ ' is described by the fuzzy subset

$C_{product\ XOR\ union}$ which membership function is

$$f_{C_{product\ XOR\ union}}(x) = f_{A_1}(x) + f_{A_2}(x) - 2 \times f_{A_1}(x) \times f_{A_2}(x) \quad (7.5)$$

This fuzzy subset usually is denoted by $C_{product\ XOR\ union} = product\ XOR\ union(A_1 \cup A_2)$ and is called the 'product fuzzy XOR union' of fuzzy subsets A_1 and A_2 .

In general the 'product fuzzy XOR union' for the elements of the 'human intelligence linguistic variable' require the computation of the membership function using (7.5)

For example if A_1 is the fuzzy subset $A_{intelligent}$ and A_2 is the fuzzy subset $A_{indeed\ intelligent}$ then their 'product fuzzy XOR union' computed with (7.5) as presented in Fig.15

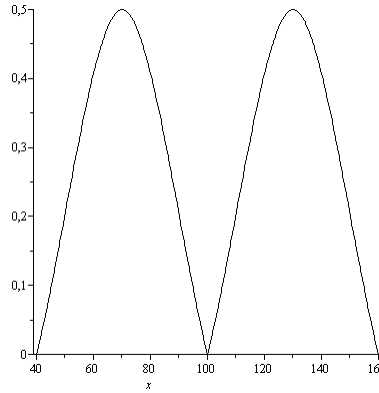


Fig.15 product fuzzy XOR union ($A_{intelligent} \cup A_{indeed\ intelligent}$)'

Representing the fuzzy statement

'*intelligent XOR indeed intelligent*' with the fuzzy subset product fuzzy XOR union ($A_{intelligent} \cup A_{indeed\ intelligent}$) a novel element of the human intelligence linguistic variable, is constructed.

We emphasize that $DOF[(x \text{ is product XOR union } (A_{intelligent} \cup A_{indeed\ intelligent}))] = f_{A_{intelligent}}(x) + f_{A_{indeed\ intelligent}}(x) - 2 \times f_{A_{intelligent}}(x) \times f_{A_{indeed\ intelligent}}(x)$.

Min-Max fuzzy logic operator XOR. [105] 'Minimum-Maximum fuzzy logic operator XOR' transforms two fuzzy statements ($x \text{ is } A_1$), ($x \text{ is } A_2$) in the fuzzy statement

$(x \text{ is } A_1) \text{ XOR } (x \text{ is } A_2)$ denoted usually with 'minimum – maximum($x \text{ is } A_1$) XOR($x \text{ is } A_2$)'.

The fuzzy statement 'minimum – maximum($x \text{ is } A_1$) XOR($x \text{ is } A_2$)' is described by the fuzzy subset $C_{\text{minimum-maximum XOR union}}$ which membership function is

$$f_{C_{\text{minimum-maximum XOR union}}}(x) = \text{maximum}\{\text{minimum}[1 - f_{A_1}(x), f_{A_2}(x)], \text{minimum}[1 - f_{A_2}(x), f_{A_1}(x)]\} \quad (7.6)$$

This fuzzy subset usually is denoted by $C_{\text{minimum maximum XOR union}} = \text{minimum maximum XOR union } (A_1 \cup A_2)$ and is called the 'minimum maximum fuzzy XOR union' of fuzzy subsets A_1 and A_2 .

In general the 'minimum maximum fuzzy XOR union' for the elements of the 'human intelligence linguistic variable' require the computation of the membership function using (7.6)

For example if A_1 is the fuzzy subset $A_{intelligent}$ and A_2 is the fuzzy subset $A_{indeed\ intelligent}$ then for $IQ = x = 71$ the following equalities hold:

$$f_{A_{intelligent}}(x) = 0.5166666667; f_{A_{indeed\ intelligent}}(x) = 0.5327777778; 1 - f_{A_{intelligent}}(x) = 0.4833333333; 1 - f_{A_{indeed\ intelligent}}(x) = 0.4672222222;$$

$$\text{minimum}[1 - f_{A_1}(x), f_{A_2}(x)] = \text{minimum}[0.4833333333, 0.5327777778] = 0.4833333333; \text{minimum}[1 - f_{A_2}(x), f_{A_1}(x)] = \text{minimum}[0.4672222222, 0.5166666667] = 0.4672222222$$

Therefore $DOF[(x = 71 \text{ is minimum maximum XOR union } (A_{\text{intelligent}} \cup A_{\text{indeed intelligent}})) = 0.4833333333$

Representing the fuzzy statement '*intelligent XOR indeed intelligent*'
with the fuzzy set minimum maximum fuzzy XOR union $(A_{\text{intelligent}} \cup A_{\text{indeed intelligent}})$
a novel element of the human intelligence linguistic variable , is constructed .

8. Results and Discussion. A computational model is constructed which is called 'human intelligence' linguistic variable. This model makes possible a new quantitative evaluation of one IQ index, depending on the kind of understanding of what means 'human intelligence' The new quantitative evaluation index is the 'true value of IQ'=DOF(IQ)='degree of membership of IQ' . Computations are presented in this framework and significant differences are revealed concerning for example: computational identification of group of persons having IQ index in a given range, meaning of fuzzy logic concepts, meaning of operations with fuzzy sets and meaning of fuzzy logic operators. This is the main novelty in this paper. As far as we know this kind of computational model for 'human intelligence' linguistic variable never been constructed. The paper is limited in application. Further research needed concerning: rules (reasoning) ,rule systems, and modelling real word phenomena in the framework of the constructed computational model 'human intelligence' linguistic variable.

Nowadays, it is common to classify scientific journals, universities, researchers, individuals based on numerical parameters, obtained by aggregating some measured parameters. Individual IQ performance indices are an example of such a numerical parameter obtained after a psychological test. Classifying a group of people based on the results of IQ number gives a precise and unequivocal result. However, there is a question related to such a result. It is concern those who use IQ numbers for classification. The question is: does the word intelligent have the same meaning for all of us? This question is natural because intelligence does not have a classic definition.

Intelligent is an ambiguous word. For this reason, an individual IQ number must be accompanied by a second number called the degree of fulfillment of the individual IQ number, which reflect a certain degree of ambiguity in the interpretation of the word intelligent. This second number is calculated using the fuzzy set attached to a concrete understanding the word intelligent and represent the confidence value (true value) of that IQ index.

9. Conclusion. A computational model was constructed which is called 'human intelligence' linguistic variable. This model makes possible a new quantitative evaluation of one IQ index, depending on the kind of understanding of what means 'human intelligence' The new quantitative evaluation index is the 'true value of IQ'=DOF(IQ)='degree of membership of IQ'

Author Contribution. Both authors contributed equally to the conceptualization, methodology, investigation, writing, and overall execution of the work. They have read and approved the final version of the manuscript.

Availability of Data and Materials. The data supporting the findings of this study are included within the manuscript.

Consent for Publication: No consent for publication is required, as the manuscript does not involve any individual personal data, images, videos, or other materials that would necessitate consent.

Conflicts of Interest: The authors declare no conflicts of interest regarding this manuscript.

Funding. This research did not receive any specific grant from founding agencies in the public, commercial or not-for-profit sectors.

Acknowledgment. We acknowledge the Department of Computer Science, namely Prof Dr. Daniela Zaharia Laboratory for encourage this research.

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- [74]. Mackintosh 1998, pp. 30–31 (<https://archive.org/details/iqhumanintellige00mack/page/30>) "In the jargon of psychological measurement theory, IQ is an ordinal scale, where we are simply rank-ordering people. ... It is not even appropriate to claim that the 10-point difference between IQ scores of 110 and 100 is the same as the 10-point difference between IQs of 160 and 150"
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