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Article

A Logic Framework for Non-Conscious Reasoning

Felipe Lara-Rosano [1]

[1] Complexity Science Center, Universidad Nacional Autonoma de Mexico; flararosano@gmail.com
* Correspondence: e-mail@e-mail.com; Tel.: +52-55-5676-3163

Featured Application: The multiple ways of non-conscious reasoning can be applied in knowledge based systems, neurocomputers and similar devices for aiding people in the problem-solving process.

Abstract: Human non-conscious reasoning is one of the most successful procedures developed to solve everyday problems in an efficient way. This is why the field of artificial intelligence should analyze, formalize and emulate the multiple ways of non-conscious reasoning with the purpose of applying them in knowledge based systems, neurocomputers and similar devices for aiding people in the problem-solving process. In this paper, a framework for those non-conscious ways of reasoning is presented based on object-oriented representations, fuzzy sets and multivalued logic.

Keywords: non-conscious reasoning; fuzzy logic; linguistic truth values.

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1. Introduction

INTRODUCTION

Non-conscious reasoning procedures in daily human life are neither typical logical ones nor are they symbolic ones. Strictly deductive schemes of thought are seen most only in textbooks about Aristotelian logic and in mathematical journals. In fact, people use less formal but more pragmatic reasoning forms to infer new knowledge from old knowledge. Inductive reasoning, analogical reasoning, associative reasoning and metaphoric reasoning are only a few of the truly human ways of thinking.

Despite this informal and qualitative way of thinking, human non-conscious reasoning is one of the most successful procedures developed to solve problems in real time.

Human reasoning is a kind of information processing in which the reasoning subject tries to discover new information about reality based on previous knowledge. To accomplish this function in a reliable way, reasoning processes must have valid logical structures to transmit the true contents from antecedents to consequents. In trying to define these valid structures, Aristotle (384-322 B.C.) founded Logic as the systematic study of the laws and forms of thought to obtain true new statements about the world by processing true old statements.

Today, Logic has left the pure philosophical field to enter the area of discrete mathematics in the form of symbolic logic. As a part of mathematics, Logic is a formal discipline using a highly developed abstract symbolic language.

However, to model human reasoning in a full way, Logic should be able to define a one-to-one mapping between its elements: symbols, concepts, propositions, laws and processes, and the semantical contents of reasoning. This is not the case. The quality and subjective meaning of ordinary concepts is not absolute but depends on the context in which the concept is used. Likewise, the quality and truth of a common proposition does not have an absolute value because the proposition's meaning varies also with the context. This makes formal Logic a necessary but insufficient instrument for handling human reasoning. Semantics, cognitive science and linguistics must then complement Logic to form the appropriate analytical framework to understand and use non-conscious reasoning.

2. Materials and Methods

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3. Results

In this paper, we analyze some characteristics of human non-conscious reasoning, and relate it with its semantic content, i.e. its meaning, and try to discover pragmatic reasoning principles and their logical foundations to better model, simulate and emulate human non-conscious (but efficient) reasoning processes.

THE FIRST PRINCIPLE OF NON-CONSCIOUS REASONING

Let us call a concept **c** the subjective logical representation of an object. The conceptual universe **C** is then a set of concepts used in a certain discourse, application or problem solving task.

The contents of a concept **c** can be represented as an ordered n-tuple $\{\mathbf{A_1(c), A_2(c), \ldots A_n(c)}\}$ of attributes. The A's span a semantic space with n dimensions. Every attribute has a value that can be quantitative, logical, or linguistic. The pair (attribute, value) express a concept property. One must define for each attribute **Ai** valid ranges **Xi** for its values. Therefore, each attribute **Ai** is a function with domain **C** (the conceptual universe) and range **Xi**. The particular instances of the concept **c** are then represented in the semantic space by points (if they have quantitative values) or regions (if they have logical or linguistic fuzzy values).

A property can be a) absolute, when it has a context-free meaning. Example: "this man is 1.70 m high" or "the car is red".

b) relative, when its meaning depends from the context, i. e. from the current application of the concept. Example: "this man is not so tall" or "this car is very expensive".

Because of their variable, context dependent meaning, relative properties are fuzzy properties that have a broader range than absolute ones and are better expressed in linguistic terms. Their values can be represented as fuzzy membership functions in the sense of Zadeh (Zadeh, 1975).

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From both kinds or properties, the absolute ones are more precise in a context-free semantics, because they represent concepts as points in the semantic space. However, when the meaning of the attributes depends from the context (and that is the rule in real world problem solving and communication), it is just the relative properties that convey the most information, because their fuzzy values express not only a region in the semantic space but the relative position of this region in the range (subspace) of the context meaning.

For instance, if we say “this boy is 1.70 meter high”, the value 1.70 meter represent a point in the scale of height but it says nothing about the relative position of this point in the current context meaning. In fact, this value means very different things whether the boy is 10 years old or 20 years old. However, if we say “this boy is very tall” this presents not only a fuzzy region in the scale of height but also the relative position of the boy's height in our context meaning.

Therefore, if we have as only description of a concept property an absolute one, then to understand its meaning in our context, we should introduce additional information relating the absolute measure with the particular context. Even in hard science applications, where all relationships among concepts have a mathematical expression, the numerical results of a lenghty computation should be evaluated with additional qualitative criteria to decide whether they represent or not acceptable solutions for our purposes.

Considering relative properties as fuzzy sets, Ezhkova (1984, 1989) has developed a method for translating absolute values to relative ones and viceversa, introducing information about the context through an experience vector and mapping the absolute values on an universal space whose scales are the universal scales for measuring attributes in linguistic labels.

Thus, we can formulate the first principie of non-conscious reasoning as following: non-conscious reasoning is based on relative fuzzy properties because they are more meaningul than absolute quantitative ones. In fact, they convey, in addition to a scale value, semantical information not contained in absolute scales.

THE SECOND PRINCIPLE OF NON-CONSCIOUS REASONING.

Because of its fuzziness, the information provided by linguistic relative properties is easier to obtain than that of absolute ones and therefore its cost is generally lower.

For example, in order to say “this boy is 1.70 meter high” somebody must measure his height with a proper instrument, according to a methodological acceptable technique and make the data available to us without distorsion. However, for saying “this boy is very tall” the measurement procedure reduces to take a look at him or at his picture and compare his height with the mean hight of boys in his context. Therefore, if we talk about his height, the linguistic communication process is more robust to noise distorsion.

Thus, we can state the second principie of non-conscious reasoning as following: non-conscious reasoning is based on linguistic relative properties because the required information is easier, faster and cheaper to obtain than quantitative one and its communication is more reliable.

THE THIRD PRINCIPLE OF NON-CONSCIOUS REASONING

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The attributes (properties) of a concept have different relevance in different contexts. Therefore we define significance **s (Ai, c, a)** of an attribute (property) **Ai** of a concept **c** in certain context **a** as the degree of relevance of the attribute (property) **Ai** of a concept **c** in the given application **a** .

Concept meaning **M (c, a)** is the fuzzy set of significant properties of a concept **c** for a given application **a**, Expressing the significance **s (Ai, c, a)** of a property **Ai** as a number in **[0, 1]** it can be interpreted as the degree of membership $\mu\, [A_i, M\,(c, a)]$ of the property **Ai** to the fuzzy set meaning **M (c, a).**

$$\mathbf{s\ (Ai, c, a)} = \mu\, [(A_i)],\ \ M\,(c, a)$$

Normalizing the significance s_i of the properties so that $\sum \mathbf{si = 1}$ we get the relative significance of the properties. These can be interpreted as the relative contribution of the attributes to the meaning. Saaty (1978) developed a matricial method to calculate the relative significance of the attributes (properties) of a given concept in certain context, by pairwise comparison of attribute significances.

Attribute significance permits to reduce the dimensionality of a semantic space and thus the amount of information to be processed by reducing the number of attributes to those above certain absolute or relative significance level. (Ezhkova 1989). This is done automatically by the human mind, which normally is not able to take into account more than seven different items at a time.

By combining two or more attributes we can define joint significances. In general, these joint significances are not functions of the single significances alone, but they depend also from conditional significances of an attribute or attribute combination given another. For two attributes then we have:

$$\mathbf{s\ (A_i \,\&\, A_j, c, a) = f\ [s\ (A_i, c, a), s\ (A_j, c, a), s\ (A_i, c, a) \mid s\ (A_j, c, a)]}$$

Certain properties characterized by a high joint significance may dominate the meaning of a concept, so that they alone become sufficient to define it. To identify a concept is to find the concept most related with a set of properties. The minimal set of properties whose joint significance permits to identify a concept is a semantic cluster. (Lara-Rosano 1991). The minimal number of attributes defining a semantic cluster is the semantic dimensionality of the concept.

If we consider a concept as a region in semantic space, then a semantic cluster is a projection of this region on the subspace defined by the semantic dimensions of the concept. This projection should be distinct enough to identify univocally a concept.

We may therefore state the third principie of non-conscious reasoning as following:

Non-conscious reasoning tries to minimize the semantic dimensionality oí concepts, that is, the number oí significant properties considered as necessary to identify a concept.

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FOURTH PRINCIPLE OF NON-CONSCIOUS REASONING

An uncertain concept is a concept that at least one of whose significant properties is uncertain. Every uncertain attribute may be modeled as a fuzzy set of values.

There are two ways to handle uncertain concepts: a) To investigate the fuzzy membership functions of uncertain attributes. b) To take as value of an attribute a default value according to some criteria.

Assigning default values to uncertain attributes instead of doing research about the membership functions is a time and cost economizing procedure. There are several strategies to assign default values to unknown properties. We will mention following:

a) To consider our previous experience with similar cases. This is called the expert experience approach.

b) To minimize the maximal possible lost, in case of assigning the wrong value. This is the minimax or pessimistic approach.

c) To maximize the minimal possible gain in case of assigning the right value. This is the maximin or optimistic approach.

From all these we can state the fourth principie of approxirnate reasoning as following: non-conscious reasoning assigns provisional default values to concept attributes when values are uncertain or fuzzy.

FIFTH PRINCIPLE OF NON-CONSCIOUS REASONING.

A systern of partitions of the conceptual universe is a very adequate instrument to organize data, decodifying the information incoming from the environment. A partition of the universe is always a qualitative one, even if the different qualities are rnathematically defined, like the different types of numbers (integers, real nurnbers, irnaginary nurnbers, complex nurnbers, etc). Organization of instances in a set of partitions is called a classification.

A partition of the conceptual universe according to some properties is called a class. The operation defining a new class is called an abstraction. A set of classes sharing some properties is called a superclass. Superclasses constitute also partitions of the universe. By combining classes and superclasses in a systematic way we get a hierarchy. A hierarchy, as a systern of partitions of the conceptual universe, represents a structural conceptual model to understand that universe. For instance, the taxonomic hierarchy of living beings, introduced by Linneo, permited for the first time to understand the whole biological world as well as to locate every living being in a conceptual framework.

We can then state the fifth principie of approxirnate reasoning as following: approximate reasoning developes and uses hierarchies on concepts as models to understand the structure of the world.

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SIXTH PRINCIPLE OF NON-CONSCIOUS REASONING

In a hierarchy, instances inherit the properties of its class and classes inherit the properties of its superclass. Syllogismus is a logical operation that rules the inheritance of properties in a hierarchy when the assignment of properties is expressed by universal and partial quantified propositions that can be affirmative or negative.

This inheritance permits to extrapolate conclusions obtained for a class to all the corresponding instances. Therefore, reasoning with classes and superclasses, also called abstract reasoning, is a very economical procedure to analyze the universe.

Thus, we can state the sixth principie of non-conscious reasoning as following: non-conscious reasoning tends to reach a generalization level abstract enough to handle very extended classes and superclasses. This permits to state general laws and principies that model and explain the universe in qualitative terms.

SEVENTH PRINCIPLE OF NON-CONSCIOUS REASONING

A true proposition is a proposition fully supported by evidence, i.e. a proposition that states a fact. There are logical operations that guarantee to state new true propositions as result if we depart from other true ones. Some of them are material implication, modus ponens and modus tollens. It is therefore very important to be able to state true propositions as foundations for our logical discourse.

A fuzzified proposition is a proposition where the predicate is replaced by a broader fuzzier concept implied by it. For instance, a fuzzified proposition of “Albert is a genius” is “Albert is intelligent”.

A true proposition logically implies all its fuzzified propositions, i.e. if a proposition is true all the propositions derived from it through fuzzification are also true. In fact, if “Albert is a genius” is true, then “Albert is intelligent” is also true

Let $a \Rightarrow b$ a true proposition: “a implies b”. Let us fuzzify the predicate b and call $b\ (\approx)$ the fuzzified b Then we have:

$$b \Rightarrow b\ (\approx)$$

Therefore, by transitivity of implication we have:

$$a \Rightarrow b \Rightarrow b\ (\approx)$$

This property let us, in an uncertain environment, to state a true proposition, by selecting a fuzzier predicate that we think contains (is implied by) a true non-fuzzy one.

Thus, the seventh principie of non-conscious reasoning states: non-conscious reasoning extends the truth of true propositions to fuzzier predicates.

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EIGHTH PRINCIPLE OF NON-CONSCIOUS REASONING

A false proposition is a proposition contradicted by evidence. A verisimil proposition is a proposition not contradiceted by evidence. Therefore, a proposition is either false or verisimil. This statement can be called the Excluded Middle Law of Verisimilitude.

The belief value **v(p)** of a verisimil proposition **p** is its degree of support by available evidence **e** and has a value in the range **[0, l]** according to its evidential support.

$$v(e \Rightarrow p)$$

The belief value v(p) of a verisimil proposition p also may be expressed as the belief value of the multivalued implication $v\,(e \Rightarrow p)$ or the possibility of p to be certain.

$$\text{Let } p = (a \Rightarrow b)$$

and substitute a fuzzified predicate $b\,(\approx)$ *for* b. Because for a broader, fuzzier predicate the possibility of **p** to be certain becomes larger, we have the eighth principie of non-conscious reasoning as following, the belief value of a verisimil proposition may be increased by fuzzification.

For defining logical operations working on uncertain propositions with belief values in **[0, 1],** a multivalued logic is required. The most appropriate multivalued logic is Lukasiewicz logic. (Smets and Magrez 1987, Lara-Rosano 1989).

NINTH PRINCIPLE OF NON-CONSCIOUS REASONING

A context is a set of empirical facts. A context, being an expression of evidence, determines the belief value of a verisimil proposition. Therefore, we have the ninth principie of non-conscious reasoning as following: the belief value of a verisimil proposition is not an absolute value but a relative one depending on the given context a.

Therefore, we may define the contextual belief value $v(p\,|\,a)$) of a verisimil proposition p as the conditional belief value of **p given a context a**.

TENTH PRINCIPLE OF NON-CONSCIOUS REASONING

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A world is a conceptual, functional model of reality. A world is expressed by a set W(p_i) of propositions describing the properties of concepts and its relationships. A fuzzy world is a fuzzy functional model of reality and is expressed by a set of fuzzy propositions. In a fuzzy world there are two kinds of propositions: (Dunn 1973)

A) Fuzzy laws. These are general fuzzy constraints or meaning fuzzy statements, referring to concept relationships and supposed to be true by evidence.

b) Fuzzy facts. They are specific fuzzy propositions fully supported by evidence.

A fuzzy world is a possible world if its laws are not contradicted by evidence. A possible fuzzy world, all of whose laws are fully supported by evidence, is a true fuzzy world. On the contrary, a fiction world is a world where at least one of its laws is contradicted by evidence. There are two kind of worlds:

a) Shallow worlds: They refer only to those entities and their relationships pragmatically sufficient to solve a problem.

b) Deep knowledge worlds: They contain the necessary cause-effect relationships to understand the genesis of a problem and prescribe its solution.

Deep knowledge worlds may be:

a) Quantitative worlds, where the cause-effect relationships are expressed by quantitative mathematical relations.

b) Qualitative worlds, where the cause-effect relationships are expressed as determinations, that is, fuzzy propositions in natural language.

Determinations may be obtained as fuzzified quantitative laws or as a step in the theory formation process as the result of repeated case experiences. They express the relevant factors to produce an effect.

Determinations may be visualized as weak theories. In fact, the determination states the existence of a relation between causal factors and effects. A strong predictive theory specifies this relation in computable form. (Russell, 1997).

Therefore, we have the tenth principie of non-conscious reasoning as following:

If determinations are obtained from observation of multiple cases, then they may be used as prediction tools for similar cases, i.e. they are the basis of analog non-conscious reasoning.

4. Discussion

Authors should discuss the results and how they can be interpreted in perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

5. Conclusions

In this paper, a framework for non-conscious ways of reasoning has been presented based on fuzzy multivalued logic, fuzzy semantics and frame oriented knowledge representation. This framework can serve as a guideline to build a fuzzy inference engines able to model and simulate non-conscious commonsense reasoning.

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