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Original Article

An Indecisiveness in Problems of Machine Learning and Artificial Intelligence

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ABSTRACT

The problem of indecisiveness is integral part in each scientific research. However, it is still not a certainty whether this problem has an objective nature. In this paper we will extend the analysis of the sources and causes of indecisiveness and define the new categories that are a stumbling block in writing high quality software. Based on a sample, we will propose several ways to classify indecisiveness. Specifically, we will investigate indecisiveness related to a human, machine and environment. In some cases, it is possible to distinguish between remediable and unavoidable indecisiveness depending on the cause.

Keywords: *Indecisiveness; Artificial Intelligence; Machine Learning*

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1. Introduction

Artificial intelligence (AI) can be described as intelligence inherent to a machine or a computer program[1]. Regarding AI as a scientific area, it is comprised of four main categories of research, one of which is - how to build systems that process information like people[2]. When comparing how much progress is achieved in these attempts - to make such systems or appropriate models, one usually do so with manufactured AI with human one. There are many cases where AI still falls behind the respective human intelligence. However, the result of that comparison can turn out to be unexpected - in completing some specific tasks AI may surpass the human one. Numerous scientific claims were proven only through the use of powerful computers. On the other hand, human intelligence is still the only one where the feelings of accomplishment and self-satisfaction are connected to the action of solving a problem. One could argue that neither are completely capable of solving certain multidimensional problems successfully. Today, we are aware of the rise of the third kind of mathematics. Apart from that, the problem of indecisiveness also exists, which is the problem of both human as well as AI.

Machine learning (ML) is seen as a subset of AI. Hence, all of the above for AI is transferred to ML by default.

It is not known when the man first faced the problem of indecision. The first serious example is found in Euclid (300 BC). His Elements is one of the most influential works in the history of mathematics. In the Elements, Euclid deduced the theorems of what is now called Euclidean geometry from a small set of axioms. Axioms are the first examples of isolated and expressed indecisions in a theory. Much later in the 19th century, as a consequence of these indecisions, a whole series of completely new geometries called non Euclidian emerged. With the emergence of new theories, none of the mentioned indecisiveness has been resolved. Only the possibility was created to obtain an appropriate geometric model, given the choice of a possible answer to some indecision. Within itself each of these theories is consistent, but mutually these theories contain even opposing claims. At the beginning of the twentieth century, science faced a sharp increase in the number of indecisions. As a rule, a new scientific discipline or direction was born for every possible answer to some indecision. For example, to the question: Do infinite exist? Intuitionists will prefer potential infinity; constructivists will eventually accept aleph null infinity, while Platonists will accept the existence of continuum infinity. During the twentieth century, the problem of indecision only kept the previously exposed direction of development. A new theory is based on each possible answer to the observed indecision.

In general, the complete development of mathematics could be divided into the following four phases. The first kind of mathematics is the one where the human states the problem, writes the algorithm and uses it to solve the problem. The second kind is where a human states the problem and makes the algorithm however, is not able to solve it, so solving is completed by a computer. The third kind of mathematics is the one where the machine sets the problem (for example, man cannot set up a system of a million equations with a million unknowns) and solves it, and the human only writes the algorithm (see [3]). The fourth kind of mathematics would be the one where all the actions are done by a machine. In all cases there exists the same problem of indecisiveness that is common for both artificial and human intelligence. The simplest reasons rise from the questions: (1) Is there a solution to every problem? (2) If a solution exists, is it unique? (3) Does the solution to any problem have a finite number of steps? (4) Is it possible to describe constructions size of the continuum infinity by the finite formal language? For example, is it possible to encode precisely all real numbers with a finite set of characters? (5) Can logic be used to describe and understand everything etc.?

Much has been written about the problems of indecision. In every book that has the word cybernetics in its title or its content, you can find many examples of indecision. A very good analysis and overview of most of the indecisiveness problems discussed in this paper can be found in [17] and [21]. As far as the authors know, one of the first papers that tried to systematize the problems of indecision was given in [4]. In this paper, following the results from [4], we will extended the research of different origins and effects of indecisiveness, define the new categories of indecisiveness and describe their nature (marked in this work with: (1.2), (1.5), (1.6) and (2.2). Using [4], this paper analyzes and deepens the problems related to indecision even more widely and completely.

2. Indecisiveness

It is intuitively understood that if the problem is solvable then a unique solution exists, not just in terms of quantity but also that it can be distinguished from anything else. In the current state of accomplishments of science and language, many questions either do not have an answer or the answers are not unique. Sometimes the answers could be even inconsistent, which cannot be dismissed or interpreted as a whole[5]. The term indecisiveness can be strictly formally defined within the Automata theory[6]. However, when indecisiveness, as in the theory of automata, is reduced to reachability, feasibility, computability... its scope is then being reduced significantly and it can become entirely irrelevant, especially if formalism proves to be a model for solving all problems. The notion of indecisiveness also becomes important in cases where certain problems do not have an algorithmic solution. The same conclusion remains even if the problem could be solved algorithmically, but it requires an infinite number of steps. The elusiveness of indecisiveness is reflected in the fact that, if any given formal theory is applied and within it there is a suitable Turing machine[7,8], then in the set of all possible language terms there may exist constructions of language objects unobtainable by a defined Turing machine. Such constructions are said to be indecisive in relation to that Turing machine. Within the same observed formal system, for all such indecisive objects, another Turing machine can be defined, complementary to the given one, in which all of these are decisive. Thus, indecisiveness becomes a term, which is only of a formal character and has no deeper meaning.

The notion of indecisiveness could be viewed as a much broader issue, related to the inability to solve a problem, as well as when there are more than one candidate for the solution or if there is a large number of possible solutions. Indecisiveness may represent the difficulty only for a human, but not for a computer, or when there is a threshold which neither man nor machine can reach, etc.

Humans approach the notion of indecisiveness pragmatically and respond to it accordingly. Often indecisiveness is resolved by choosing one of the possible solutions, until the practice causes the subject to doubt it and proceed for a different option. Almost all indecisiveness is "resolved" through the choice of one of the options. This way, it is assumed that humans are capable of coping with the problems of indecisiveness. Humans transferred this approach to automata as well[8]. There are cases of indecisiveness that do not require a human to make a decision. These are kinds of indecisiveness that are not directly related to them, so it is not necessary for them to make a choice and they can maintain their freedom and independence. On the other hand, today it is expected that machines behave decisively. At the core of algorithms is decidability and thus indecisiveness is ruled out. This is going to be changed very soon (see [9]), and indecisiveness will be given its real value.

AI requires a developer to make a very general algorithm, which is capable of completely replacing the role of a man in a particular task. This kind of expectation is understandable, however, not practically feasible. There are many open questions that are impossible to be answered adequately with the current level of science (for one example see [10]). For example, is it possible for the algorithm to recognize that the solution it will propose is exactly the one requested? This problem is always arising when solving cryptographic tasks (for some detail see [11]). Human intelligence can be far superior than AI, which developers incorporate into the algorithm aiming to solve a certain problem. This creates the problem of local and global intelligence. When we have a limited approach, reducing the problem to local intelligence, perhaps it may never be possible to simulate human intelligence, which is global. Apart from this, indecisiveness of the result, there is a whole series of other indecisiveness, some of which are discussed in more detail in this paper.

3. Types of Indecisiveness

There are many different ways to define indecisiveness. The basic classification is based on the question: Does all indecisiveness have removable nature? Based on the answer to this question, two disparate types of indecisiveness can be recognized:

(1) Unavoidable indecisiveness, which is present: when the problem has no solution (does every problem need to have an algorithmic solution?) or if it is not clear how to choose among several possibilities (see [12]), (each one is true to itself and in itself) or when it is not possible to integrate all possible solutions or the number of solutions is not finite, etc. We can characterize such indecisiveness, at least for the time being, as objective. If such indecisiveness exists objectively, then indecisiveness is an essential concept of every theory and, within it, has great importance and value.

(2) Removable indecisiveness, which is present: when the problem has more than two solutions, but it is possible to make the selection supplementing some additional conditions or some auxiliary method to check and eliminate the remaining possibilities[12], until single one remains, or to enable additional derivation by changing of formalisms or by changing the sensitivity threshold in order to be able to differentiate between apparently the same objects, etc. This kind of indecisiveness is consequence due only to specific restrictions, which can be eliminated. Indecisiveness in this sense is only pseudo indecisiveness. It is justifiable to ask: "Could it be that the indecisiveness that cannot be eliminated is due to certain restrictions?" Yet, we are still not able to recognize or to grasp these restrictions or to determine their nature.

Irrespective of the fact that indecisiveness has the objective nature or not, one can distinguish three types of indecisiveness: (**Figure 1.** Schematizes the division.)

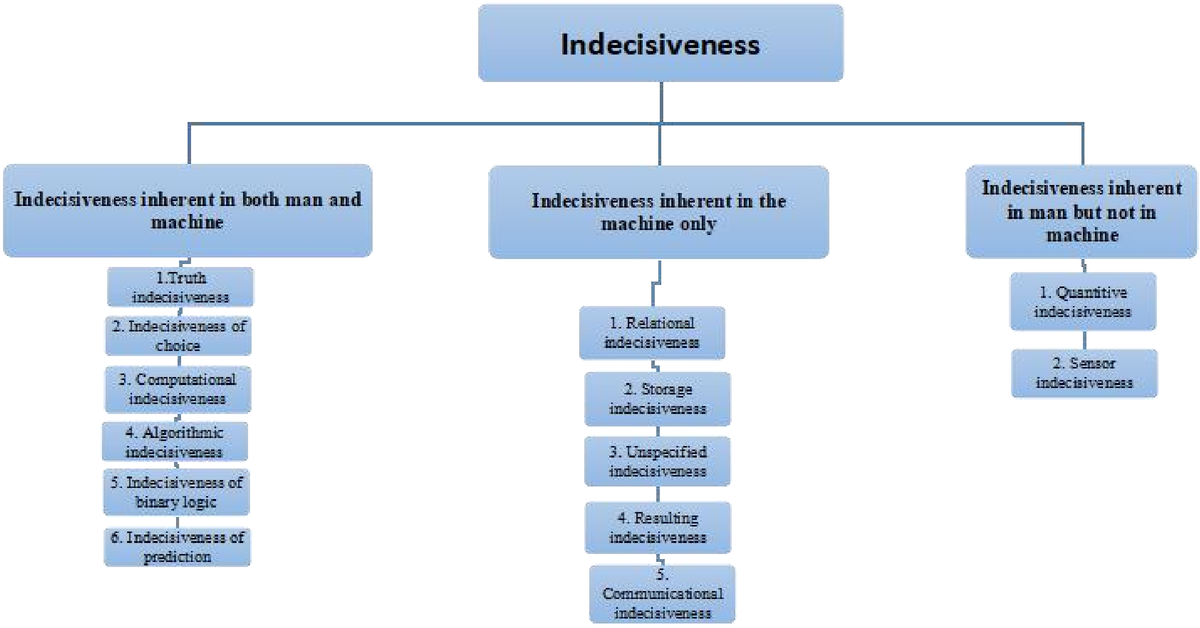

Figure 1. Schematizes the division.

(1) Indecisiveness inherent in both man and machine. It is related to concepts for which humans do not yet have an adequate definition or to problems that they cannot yet solve. Nowadays, such the indecisiveness can be found in determining the existence of infinity (see [13] for details), and originates from the fact that nowadays axiomatic setup of mathematics does not allow a conclusion to be drawn about neither the existence nor the nonexistence of objective infinity.

(2) Indecisiveness inherent in the machine only. Indecisiveness not inherent to humans and, at the same time is still unsolvable for the machine is, for example, the one contained in unspecified conditions[12] when solving logical problems. When solving some logical problems one sometimes uses conditions which are not specified explicitly, however a human can assume these to hold from the context. That is basically the relationship between local and global intelligence. If in the future a machine is built that can simulate global intelligence, all indecisiveness of this type will disappear.

(3) Indecisiveness inherent in man but not in machine. Such indecisiveness is related to solving problems having volume and physical complexity that restrains humans, while for a computer that is fast and powerful enough, these can also represent difficulty however, a manageable one. Numerous mathematical problems are resolved in this manner. In this category belongs a problem of sensitivity threshold and detection, as well as distinguishing between signals, tones, colors, etc. This type of indecisiveness is stemming from the fact that man already has skills necessary to create machines that, in many ways, can surpass human capabilities. Can this process be successfully continued with the remaining human abilities? Answering that question with only yes or no, without further solid argumentation to support it, certainly would cause many to dissent.

These kinds of indecisiveness can now be enumerated further and exposed in detail. From the point of view of writing the program or coding, the second and third kind of indecisiveness deserve far greater attention.

(1) The indecisiveness inherent in both man and machine can be divided into six categories:

(1.1) Truth indecisiveness. The truthfulness problem is for now objective because there is no strict definition of the concept of truth. The question, what is the truth (see [14]), will be left without an answer in the long run within the current level of science. Not even all the parameters that serve to recognize the truth could be at the same time possible to implement practically. It is difficult, or rather impossible, to check what is valid "forever and ever". This kind of indecisiveness will exist, until the scientific level is reached from which one can accurately and undoubtedly establish what is true and what is not. When and if that becomes possible, it is likely that many out of present scientific truths would be changed significantly. In its current state of matters, it is objectively impossible to train a machine to determine truthfulness, unless it is strictly formally clear to a human as well.

In a natural language, with respect to accuracy, there exist quite diverse sentences. The most challenging case are sentences that are, at the same time, both true and false[15]. Such a paradox can be the result of the fact that we are not able to define the term "truth" however; it is not necessarily the cause of such a phenomenon. Examples of truth indecisiveness are well known in geometry for a long time[16]. For example: "There is only one line that passes through two distinct points." Through the given point that does not lie on a given line there is one and only one line that lies in the plane determined by that point and the given line, and does not intersect the given line. Such sentences can be used correctly in geometry within the given theory in both cases: when we consider them true and when we consider them false. The obtained theories can be proved to be consistent within themselves, although it is quite clear that they are essentially different. There is no fewer problems with sentences that have no truth value. Given the current level of technology, it is objectively impossible to enable a machine to establish truth, if it is not strictly formally clear to a human, too.

This group of indecisiveness has a series of subcategories of indecisiveness, which are all consequences of the problem of truthfulness. Thus, we could classify in this group: axiomatic indeterminacies (related to the choice of axioms)[32], theoretical indecisiveness (by different choices of axes we create different theories that are within itself consistent while mutually inconsistent), etc.

(1.2) Indecisiveness of choice. One of the inductors is the previous type of indecisiveness. We single it out as a special type of indecisiveness because it can be manifested in two forms: inherent only in a machine and as inherent in both human and machine. Electoral indecisiveness arises in response to the problem of whether it is possible to make an algorithm, which can distinguish some elements from a set of all similar ones. One of the well-known indecisiveness of choice is related to set theory. The question has justifiably been raised as to whether, on the basis of each aggregate property, it is possible to determine for each potential element whether it is an element of the set or not. For example, barber paradox: barber lives in one village, "who shaves all those who do not shave themselves" - it is a gathering property for the inhabitants of a village[18]. The problem is that this barber cannot appear either as an element of a group of people who do not shave themselves, but also as an element of a group of people who shave themselves. In an attempt to include a barber, as an element of such a set, we encounter the problem of indecisiveness of choice. Linguistic indecisiveness also belongs in this category[17]. Every language is a formal creation and as such by default contains indeterminate constructions, i.e. the impossibility of determining whether a given construction is an element of language or not.

(1.3) Computational indecisiveness. In this case we can differ two types of indecisiveness: one characteristic to humans and another to humans and computers.

When it is unique to humans, this kind of indecisiveness is referred to as algorithmic interruption[20]. If a man had to solve a linear system with randomly given coefficients with only eight equations and eight unknowns, with Cramer's rule it would last at least his whole life (see [3] for some details). In this section, we consider the indecisiveness inherent in both man and machine. With such indecisions, the machine can significantly surpass man, but it also always has limitations. There are numerous examples where a machine has solved a problem, which was realistically unattainable for a person to solve. The time that a person would need or the complexity and volume of work are such high thresholds for a person, that it is almost impossible for a person to reach a solution, but for a machine it does not have to be a stopping limit. But the machine is also objectively always finite and limited. That is why for a machine, no matter how much it increases its threshold, there will always be problems with solutions that exceed every pre-set threshold. In this case, indecisiveness is related to the fact that it is not possible to obtaining a solution(s), although they exist and are finite.

The existence of actual infinity is not a necessary condition. If infinity is potential, indecisiveness is an essential problem, given computability. Within such an indecisiveness, the following problem takes the central place: Is every computable function recursive, that is, can it be calculated gradually in steps? Is computability always finite? Church's thesis on recursive functions[19][21-33].

(1.4) Algorithmic indecisiveness. A very justified question is: "Is every problem has an algorithmic solution, and if so, does the algorithm necessarily have to be finite?" This is a hypothesis that is assumed to be true nowadays. However, there is no certainty that this is actually the case. On the other hand, it is still not possible to determine the truth of that attitude. This assumption was also used by Gödel in the proof of the existence of indecisive attitudes in arithmetic[23]. If there are algorithms that are not finite in nature, then they are objectively excluded from the scope of the machine, which by its nature will be finite. The next important question is: "Are finiteness and infinity continuous concepts?" If they are not, then it is meaningless to assume that a problem is algorithmically solvable if it can be solved by an algorithm in infinitely many steps. Potential discontinuity forever separates the path from the goal. No matter how much human consciousness and knowledge increase, it will always remain unknown whether humans are capable of encompassing the entire universe, provided that the universe is actually infinite.

(1.5) Indecisiveness of binary logic. There are clearly defined dual states in cases where there is no dilemma. For example, magnetization - non - magnetization or there is electric current - no electric current, etc. In such cases when we determine that one of the states is inactive, then its dual state must be active. Such reasoning could be problematic when one wants to easily extend it to other seemingly dual states. For example: finite - infinite, dependent - independent, etc. When we determine that something is not finite, that cannot be the justification of its infinity. The reason is that, even though such states seem to be dual, they are actually not.

Gabriel's Horn[24] (also known as Torricelli's Horn) is a solid that has a finite volume but an infinite surface area. Such a body can be said to be both finite and infinite at the same time. Fractals[25] are structures with dimensions that are not integers and therefore cannot be represented in a space with integer dimensions. Such bodies cannot be held to be neither finite nor infinite. Given that, the terms finite and infinite are not considered to be dual concepts, and need to be considered as at least four states: finite, infinite, finite and infinite, and neither finite nor infinite. The idea of such uncertainty can only be extended to other examples. Currently, it is not possible to exactly define what can be considered to be a dual state phenomenon.

Fuzzy logic can only partially help in such cases because it only increases the number of possible outcomes and does not solve the cause of indecision[34].

(1.6) Indecisiveness of prediction. In almost all intelligence tests today, the following task can be found: Given the sequence 2, 3, 5, 9... determine the next term. It is almost certain that the presumed answer will be number 17. However, even with the greatest effort of the author to notice it, such questions do not have a unique solution. The correct answer could be any possible number. When solving such problems, one is expected to find a formula that uniquely defines the next term in the sequence. Since there are infinitely many formulas there is actually no a unique answer. More precisely, the formula will give a unique solution but the formula itself is not unique. In the given example with a complex formula:

$$f(n) = \frac{1}{6}(n^3 - 3n^2 + 8n + 6) + (n-1)(n-2)(n-3)(n-4)g(n) \tag{1}$$

it is easy to check that the next member of the above sequence can be any number. The error of this task lies in the fact that the author assumes the determinism of the world as the exclusive feature of the world. Due to objective coincidence, it is not possible for the time being to make a correct prediction with any deterministic tools. Therefore, in any deterministic model, this kind of indecisiveness cannot be avoided.

(2) The indecisiveness inherent primarily in the machine are:

(2.1) Relational indecisiveness. In certain sentences, it is impossible to correctly determine the subject and the object. For example, in the sentence: The dog, which my brother petted on the way to school, bit him. Sentences like this are usually thought to be taken out of context, which is not necessarily true. It is possible to imagine the text in which this sentence is contained, but even so, it is not possible to determine with certainty who bit who. This problem is not only related to some languages, it is present in all-natural languages, even in those that have strict rules about the order of words in a sentence. Such indecisiveness is a consequence of the fact that language is of a formal nature. Any formalism necessarily induces indecisiveness[16].

(2.2) Storage indecisiveness. The computer, like a human, has its limitations. It can increase its resources, but ultimately remain finite. Although, even today, the machine surpasses man in its computational capabilities, it will always remain limited by some value. This numerical value, no matter how large, will represent the computational threshold. Numbers written with one hundred digits represent quantities, which exceed any known quantity in the known universe, but are only insignificant numerical values with respect to numbers of one hundred thousand digits, and so on. From this point of view, the storage indecisiveness will probably last and remain as such, no matter how much the computer's hardware performances increase[21].

(2.3) Unspecified indecisiveness. Many problems involve some conditions that are not explicitly given. They are the result of a person's habits, inclinations or acquired prejudices with which a person unites in the process of his socialization. A much bigger problem is that such conditions are not equal in different social communities, which further complicates this issue. By unifying the social community, there can be unification in the method of observation and assumptions of all human beings, but the problem remains. When solving more complex logical problems, the creator of the task must count on the fact that the solver will resort to the use of unspecified conditions, which are implied by the context. For example, in search of a murderer among a given number of suspects, if it is not assumed during the decision that only one person is the murderer (example from [27]), an ambiguous solution can be reached, and thus one faces indecisiveness - when to accuse? The possibility of more conspirators should not be ruled out as a solution, but one cannot be accused, just because one cannot be ruled out. Such conditions are never given, but if they are not used, the task does not get the real meaning, because the solution becomes ambiguous. How to reach such conditions in writing a general algorithm is a problem for which we still do not have the right solution.

(2.4) Resulting indecisiveness. This indecisiveness most often occurs in problems related to cryptography. When a program is written that decrypts a message, the problem of recognizing the obtained solution as objectively true arises. How a computer could determine that the resulting solution is exactly what is desired is a challenge. Theoretically, it is possible that the solution was written cryptographically, in the sense that it was given in another language, which is not specified. The solution can also be a number, but written on an unknown basis, which has yet to be found, etc. It is very difficult to imagine that in the foreseeable future this problem will be able to be finally and clearly resolved. The problem of the relationship between local and global intelligence is especially present here. The algorithm has local intelligence. In order for the algorithm to have global intelligence, it would have to be able to solve every solvable problem. If there were different special algorithms to solve different classes of problems, is it a given, that for global intelligence, they would all have to be part of a single algorithm. This leads to the conclusion that the problem of AI is the development of a unique algorithm.

(2.5) Communicational indecisiveness. It is also known as "noise". This indeterminacy can be reduced by redundancy (if the binary signal is faulty, repetitive, or signal renewed, although in analog technique noise is usually removed by filtering). In addition, according to probability theory, there can always be errors, which can be repeated any number of times[29]. In this case, we come to the situation that in addition to humans and computers, a third party is introduced, and that is space or communication medium (an obligatory part of the communication system, even computer networks). The problem of indecisiveness is no longer related only to the shortcomings and limitations of humans and computers, but also introduces all possible problems of the environment as potential causes of indecisiveness.

(3) Indeterminates inherent in humans, but not in machines, are:

(3.1) Quantitative indecisiveness. The name suggests that this indecisiveness is not essential but only apparent. It occurs in problems where there are a large number of cases that need to be checked, and at least the time required for that is not available to the person. For example, it would take a human 1000 years to search all the possibilities. An example of this is to determine the minimum sudoku setting on a 9x9 board. It took the superfast computer exactly one year to prove that there is no starting position which uniquely determines a solution with 16 initially given digits[26]. There are quite a few similar examples today.

(3.2) Sensor indecisiveness. A computer can recognize and distinguish tonal or optical - something that a person cannot. It is well known that the human senses are limited. Humans can hear only tones between 16 and 16000 Hz, see light rays only in interval of wavelengths from 3500 to 7000 angstroms, etc. Humans have a limited resolution of the points they can see, while optical sensors can also detect images with incomparably higher density and transmit them to the computer. Hence, the images that are essentially different are identical to the human eye (for example, they recognize that the same object has been painted several times, only from different angles), while for a machine they are not. Sometimes a person integrates signals during detection, which are received by different senses. In some situations, it helps a person react better, but also to make mistakes faster, i.e., the sense of sight can deceive the sense of hearing.

Some images are better recognized by computers than humans, but there are also reverse situations. It uses the CAPCHA test (acronym for Completely Automated Public Turing Test to tell Computers and Humans Apart) to check if a human or machine is trying to access some content on the Internet. Typical examples are blurred images or strings of distorted characters. People can easily recognize and read these, whereas computers are much slower (or still unable to)[30].

One cannot distinguish sounds with the accuracy with which a sound or tone sensor can, and therefore a computer as well. A computer equipped with adequate sound sensors can distinguish external phenomena and objects significantly better than a human, and in that sense it has incomparably wider intervals of determination than a human. Indecisiveness in this case is the impossibility of distinguishing between different objects[31]. For example, for some two objects one would say that they are the same, and they are essentially different, which machines can recognize.

4. Conclusion

The basic problem with indecisiveness is to define its cause. It is necessary to determine whether determinism is the root cause of indecisiveness within an observed system? Our view is that the notion of indecisiveness has a much broader cause. The notion of indecisiveness will have an objective character until science is able to:

(1) Defines the concept of truth.

(2) Determine the objectivity of infinity; A large number of other concepts directly depend on the concept of infinity (continuity, measurement, motion...) and numerous paradoxes arise.

(3) Finds a way to unite different formal theories into a single theory. Formal theories are by definition the cause of indecisiveness.

(4) Combine stochasticism and determinism; This gives up the uniqueness of the solution to the problem as well as the logic that only leads to the solution.

(5) Create global AI. This would partially eliminate the problems of indecisiveness related to the machine. The development of the fourth kind mathematics leads to this goal.

It is very important to distinguish between indecision in relation to man and machine, while the external environment must not be excluded. The indecisions that we have classified as objective, and for which it can be shown in the future that their threshold has changed, also deserve special attention. In that sense, it is very important to carefully investigate the causes of certain indecisions and the ways of their eventual elimination.

Conflict of Interest

The authors declare that they have no conflict of interest.

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