Where is the Intelligence in Computational Intelligence?

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Abstract

Intelligence is a controversial term to define in a universally acceptable way. However, the term is very frequently used in various fields of computer science like web intelligence, machine intelligence, artificial intelligence and overall in the computational intelligence. Some sort of intelligence has already been introduced to different advanced technologies. The future advancement of the intelligent technologies requires a clear definition of intelligence to work with. This paper tries to find out the answer of the crucial question, where and in which cases intelligence might exist in case of intelligent technologies and in the field of computational intelligence in general.

Keyword – Intelligence, Machine, Artificial Intelligence, Agents, Semantic web

1. INTRODUCTION

'Intelligence' is a term that we often use in our daily lives and also in various scientific fields. Often we classify the level of intelligence in our real lives by using the words; *bright, dull, smart, stupid, clever, slow,* and so on. The term itself might be a simple word with only twelve letters, but the combination of these twelve letters creates a great confusion to formulate a universally acceptable definition of '*Intelligence*'. In fact, it has got some authority as it is widely used in many situations and might be used for referring various concepts in different fields of science. The dictionary meaning defines intelligence as "*The capacity to acquire and apply knowledge by means of thought and reason.*" [1]. A scientist might define it as a large collection of human cognitive behaviors or the human thinking power; to a psychologist it is the ability to perceive, pose and resolve problems; a life scientist might define it as the capabilities of an animal for doing a task. Whatever the usage of the term for other fields, in computer science, the term 'Intelligence' has various utilizations in various particular fields; it could be used for

artificial intelligence (AI), could be for machine intelligence, could be meant for intelligent agents or might be computational intelligence. The intent of this paper is to analyze and focus on the existence of intelligence in computational operations.

This paper is organized as follows: Following the section 1, section 2 discusses human and machine intelligence, section 3 deals with computational intelligence and its extent of applicability in reality, section 4 mentions how intelligence could be incorporated with the web technologies and section 5 summarizes and concludes the paper.

2. HUMAN AND MACHINE INTELLIGENCE

2.1. What is Intelligence?

Definition of 'Intelligence' is basically domain specific. However, computer science and cognitive science define 'Intelligence' as a combination of the capabilities, [3]:

- To respond to situations very flexibly
- To take advantage of fortuitous circumstances
- To make sense out of ambiguous or contradictory messages
- To recognize the relative importance of different elements of a situation
- To find similarities between situations despite differences which may separate them
- To draw distinctions between situations despite similarities which may link them
- To synthesize new concepts by taking old concepts and putting them together in new ways
- To come up with ideas in new ways

The essence of this definition (if we accept it!) is the understanding of specific situations and acting accordingly with the help of prior knowledge. This indicates that, a good knowledge base with a thinking mechanism is needed to show the sign of intelligence.

Intelligence could be of two forms: conscious and non-conscious. Definitely human

intelligence has the consciousness while machine intelligence is practically non-conscious. Based on the consciousness in the intelligence, we could divide intelligence into four categories:

- Biological non-conscious (exists)
- Biological conscious (exists)
- Mechanical-electrical non-conscious (exists)
- Mechanical-electrical conscious (not yet been invented) [1]

Some examples based on the consciousness of intelligent are mentioned here (taken from [1]):

a. Insects building a nest (consciousness uncertain)

b. Animals foraging for food. (conscious, but some philosophers still debate this)

c. Apes climbing a tree. (some self-consciousness)

d. Humans inventing a machine. (self-conscious)

e. Robots performing mundane tasks (unconscious)

f. Computer algorithms solving a navigational problem (unconscious)

g. A chess program beating the world's best grandmaster (unconscious)

All of the examples mentioned here indicate that, some sort of thinking power is at least needed for performing these sorts of tasks. The development of this thinking power for the machines is the major concern for artificial or computational intelligence.

2.2. Intelligence for a machine?

Computerizing a human being or humanizing a computer is an interesting field of research in HCI (Human Computer Interaction). How can a machine be humanized? – might be by infusing some sort of intelligence into the machine. We know that at least to some extent, computers are human like and the humans are also computer like. If we take a look at the basic functional units of a computer we find that they include the input/output (I/O) channels, memory and processor. Doesn't a human being possess all of these? The basic functional units of a human being resemble with those of a computer. Human beings also have the I/O

channels like Iconic (eyes), Echoic (ears) and Haptic/Touch (skin) channels, the memories like sensory memories (like Random Access Memory, RAM), short-term or working memories (Like cache memory of computers) and long-term memories (like computer hard disk), and human brain that could be termed as the natural processor. If we apply the reverse logic, it could be said that, computers are also similar to the human beings at least on the basis of the basic functional units. So, what is the major point that makes human beings superior? The answer could be - the '*Natural Intelligence*'. A formal definition of a human being is often given as:

A very Smart and Mysterious (!) embedded real time system having the capability of processing information ***intelligently*** *via a number of Input/Output channels.*

Can we define a computer or a machine using the same collection of words? Most probably the major difference is created by the word, '*intelligently*'. If this term has so much gravity, then can't we inject intelligence into the computers so that we could make human like computers? Let's look back at the history a bit. Human beings tried to develop a machine which can do work for them (as they wanted to be lazier!). As a result of their endeavor, computers were introduced. However, to speak the truth, a perfect thinking computer with a perfect intelligence has not yet been perfected, in fact that is far away from reality at present. Even if we think spiritually, humans are said to possess soul, essence of life; on the contrary computer is simply a machine dedicated for its soul purpose, being instructed and accordingly execute one or more predefined functionality, decisive functions on its own is not possible. So, how comes the use of the term 'Intelligence' for the computers or computational operations?

2.3. Intelligent agent and Computational Intelligence

Computational Intelligence, a term coined in the early 90s, is a coherent and symbiotic collection of information technologies, namely fuzzy sets, neural networks, and evolutionary computing [4]. Actually, computational

intelligence is the field where intelligent agents are dealt with. An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors [5]. An Agent could be a worm, a dog, a thermostat, an aero plane, a human being, an organization or a society. An intelligent agent is something that has intelligence and it acts intelligently depending upon the situation. Figure 1 shows the pictorial representation of an intelligent agent. Basically, the central scientific goal of computational intelligence is to understand the principles that make intelligent behavior possible, in natural or artificial systems [6].

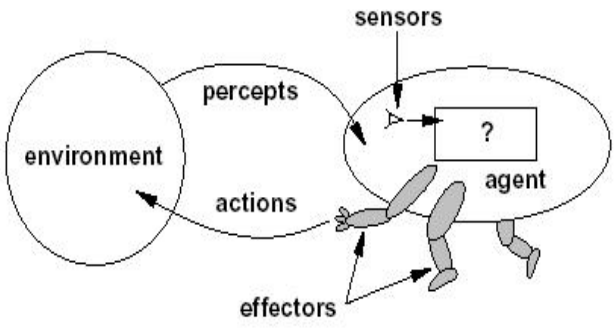

Figure 1: Intelligent Agent

What is rational or intelligent at any given time depends on four things [5]:

- The performance measure that defines degree of success
- Everything that the agent has perceived so far; that is the ***percept sequence***
- What the agent knows about the environment
- The actions that the agent can perform

This eventually leads to a definition of an ideal rational/intelligent agent:

For each possible percept sequence, an ideal intelligent agent should do whatever action is expected to maximize its performance measure, on the basis of the evidence provided by the percept sequence and whatever built-in knowledge the agent has. [5]

3. ARTIFICIAL OR COMPUTATIONAL INTELLIGENCE?

Artificial intelligence (AI) or computational intelligence (CI), what should be the appropriate term of the field in which we deal with intelligence (non-conscious)? Although there is no clear definition of AI (not even of intelligence), it can be described as the attempt to build machines that think and act like humans, that are able to learn and to use their knowledge to solve problems on their own [7].

In another way it can be said that, AI is the established name for the field we have defined as CI, but the term "artificial intelligence" is a source of much confusion. Is artificial intelligence real intelligence? Perhaps not, just as an artificial pearl is a fake pearl, not a real pearl. "Synthetic intelligence" might be a better name, since, after all, a synthetic pearl may not be a natural pearl but it is a real pearl. However, since it is claimed that the central scientific goal is to understand both natural and artificial (or synthetic) systems, we prefer the name "computational intelligence" [6].

CI or AI falls into two broad categories: a scientific side (also known as cognitive science), devoted to the development of theories of human intelligence, and an engineering side (also known as applied AI), devoted to the development of programs that exhibit intelligent behavior, whether of human or nonhuman quality [8]. While the former is possible (to a limited extent though) with today's computational intelligence or artificial intelligence techniques, a part of the latter e.g. human like behavior is still far from the day that this would be real. If we give a machine a task and are happy after the machine finishes its tasks, this might not be a good approach to develop something like *real intelligence* for the machines. The researchers found that it is better to attack the way the machine solves the task.

3. 1. How much Intelligence for a machine?

Intelligence is a difficult term to quantify. When we use the term, it obviously depends on the situation at hand, thus the use of the term is relative. Let us consider that, our target is to inject some sort of intelligence into a machine. But, before starting the task we need to have a clear vision of the whole scenario. How much intelligence we can infuse to a machine? Let us analyze the problem domain with two examples. Firstly a puzzle:

Three persons *A*, *B* and *C* are wearing three hats. The hats are of only two colors, either white or black and both the colors are used. So, for three persons we have only two colors

available. Surely at least two of them are wearing the hats with same color either black or white. Now, the problem is, they don't know which colored hats they are wearing, none of them; only they can look at each other's hat and it is not possible at all for anybody to point his eyes to the outer color of his own hat. They are told to find out the colors of the hats they are wearing. Let us make it simpler for illustrating the situation. Suppose, person *A* has a black hat on his head, person *B* is wearing a white hat and person *C* is wearing a black hat. Figure 2 shows the situation. Now, question is; who is in the best position to find out his own color? Obviously the person named *B*. How can we deduce this? Just by employing the logics or our intelligence. Our reasoning tells us that, person *A* sees; *B* has a white hat, *C* has a black hat. So, *A* is not sure which colored hat he has. Now, person *C* sees; *A* has a black hat, *B* has a white hat. Hence, *C* is also confused.

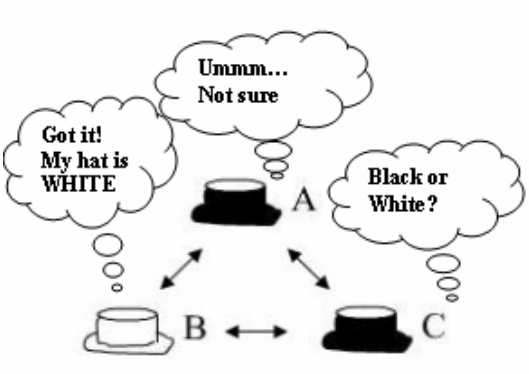

Figure 2: The hat-color problem (initial)

However, person *B* has a different situation. He sees; *A* has a black hat, *C* has a black hat, as both of the colors are used and above condition exists, definitely he is wearing a white hat!

At this stage, we can say that, a close observation and some logical reasoning lead *B* to take the decision. Can't we make a computer this much intelligent? Of course we can. A set of inference rules and some reasoning or some 'if-else' conditions in the programming code might be enough to give this power to a processor.

Let's think a bit deeper. Let us consider that in our hat-color problem, *B* has formally declared his hat's color and it has been officially

justified. Now, *A* or *C* should make a decision of their hats' colors. Analyzing the current situation we find: Person *A* finds; *C* is wearing a black hat, *B* was wearing a white hat. So, *A* is still puzzled as his hat could be of any color. Person *C* is also in the similar situation. From *C*'s point of view; *A* is wearing a black hat, *B* was wearing a white hat. So, again the confusion remains.

Here comes the question of utilizing a strong set of logics or something more than that. Before taking a decision, *A* or *C* must understand why *B* has got the right answer to find out his hat's color. If and only if either *A* or *C* could understand *B*'s reasoning and solving method, only then, anyone can take a final decision about his own color. Suppose, in our case *A* could find out the exact answer and won over *C*. What could be the logics available from *A*'s point of view? The logics could be (what *A* found); *B* has got the answer by seeing our hats' colors and declared his hat's color as white. What is the reason so that *B* has detected the right answer so easily? Most probably we (*A* and *C*) are both wearing the same colored hats. Now, as *B* has declared his color as white, definitely we are wearing black colored hats! Figure 3 shows the situation.

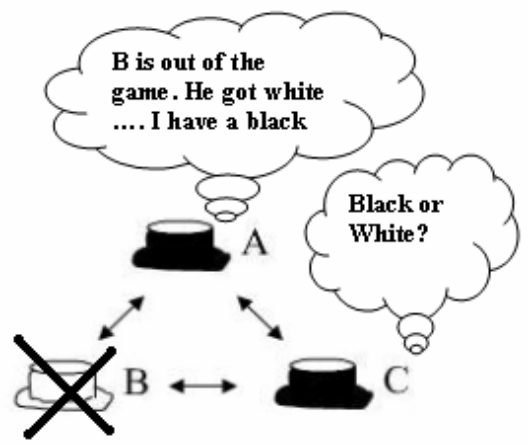

Figure 3: The hat-color problem (B is out of the game)

A human being can draw such a decision by utilizing his strong logical reasoning techniques or intelligence. In our case, as *A* has more intelligence (at least in this example), he could answer before *C* could. Can we inject such type of intelligence within a machine? In Computer Science, Artificial Intelligence or Computational Intelligence is dealing with this. With today's advancements of intelligent technologies, this sort of intelligence is also possible to simulate using programming codes and other available techniques.

Let us proceed to the second problem. Consider the situation that, I am now sitting in my room and I know that a doctor's chamber is on my right and a medicine research lab is on my left. Suddenly I got a very severe headache. What could be the better option for me? Suppose, the medicine research lab has some brilliant researchers who are working on headache or inventing medicines for headache. Would I tell my colleagues to take me to the lab for making me a subject of experiment or would I prefer the doctor's chamber? May be the top researchers are working in the lab; doctor's chamber would still be the better choice for me. What type of decision making technique or intelligence should I have for taking such a decision? In this case, I don't need a strong set of rules to find out a solution rather a simple reasoning is enough. Is not it puzzling? In the first example, we are saying A is intelligent as he possesses a strong reasoning technique while the second example says; absence of strong set of logics is the intelligence!

The major point comes out from this is the presence of good knowledge base and use of it based on a particular condition. A sophisticated artificially intelligent program might suggest me to go the research lab but depending upon the situation it could not be termed as intelligence. Can we make a machine so intelligent with such type of decisive function? If not, where is the intelligence?

Before concluding this section, let us deal with a third problem to support my stand. Being computer scientists we deal with mathematics and logics. Suppose, I am assuming that, I will pass the intelligence of recognizing a bird into a machine; say my own computer. I have set the logic like this; "Birds can fly". "An albatross is a bird". So, at this stage, my computer can deduce "An albatross can fly". Now, I have set another statement, "Penguin is a bird". What could be the result from this sort of intelligence? "Penguin can fly"? Well, I need to place another statement, "Penguin is an exception among birds". Hence, my machine gives the output, "Penguin is a bird

which is an exception" or "Penguin cannot fly". Now, think that, I am putting another statement, "Aero plane can fly". My simple intelligent (!) program might say, "Aero plane is a bird!". To check such type of mistake I need to put the statements like, "Birds are living objects", "Aero plane is an inanimate object". This is often the case that things that look simple at first sight can turn out to be real difficult or real tricky. Only some reasoning techniques and a set of inference rules are not enough for developing intelligence for a machine. Rather, the machine must have a large amount of knowledge base which it could use with the collaboration of inference rules depending on the gravity of the situation at hand.

4. INTELLIGENCE FOR THE WEB

Now-a-days when we search for any particular information in the Internet, even a single click may bring megabytes of data over half of the globe, may easily get lost by groping in the "darkness" of the network, or be bored by taking many hops and waiting impatiently for a piece of information . For efficient searching, research on including some sort of intelligence has been started which eventually gave birth of the semantic web technologies. The semantic web is a new form of Web content that is meaningful to computers. It aims at achieving better performance for search engines, where the users could find pages that contain semantically similar but syntactically different words and phrases, for using it in web and grid services [12, 13], where rich service descriptions could be provided and for using in e-commerce, where communication between buying and selling agents could be facilitated to describe goods and services [11]. The researchers are trying to write some kind of soft robots or softbots which will crawl through the web, combine pieces of information across the globe and will present in front of the user; thus will reduce the burden of surfing through the web for any particular information. Will not it be helpful if an intelligent web robot or softbot does work for us? Whether or not the semantic web as a concept remains unclear, it is clear that a

shake-up of the web is required to make it more meaningful, respond faster to questions, and join up disparate information objects and sources automatically. It's not computer intelligence as such. Let's just call it computer common sense [9].

The researchers are now working on introducing intelligence for all of the web technologies. A novel intelligent Web theory called computational Web intelligence (CWI) based on computational intelligence (CI) and Web technology (WT) has been already introduced [10]. Another concept is the hybrid Web intelligence (HWI), which is based on artificial biological and computational intelligence with Web technology. HWI is used to build hybrid intelligent Web systems that serve wired and wireless users more efficiently. Six major CWI techniques are: fuzzy Web intelligence, neural Web intelligence, evolutionary Web intelligence, granular Web intelligence, rough Web Intelligence and probabilistic Web intelligence. With the huge potential for intelligent e-business applications of CWI and HWI, these techniques represent the future of intelligent Web applications.

5. SUMMARY AND CONCLUDING REMARKS

The title of this paper is basically a question. Quest for the appropriate answer eventually generated a series of other questions. At this point, the original question could be answered as: Computers or machines are not like human brains, but if they perform the same acts (to a very limited extent though) and one performer (the human) is labeled intelligent, then the other must be labeled intelligent also [2]. But how much intelligent? Can we make a perfect thinking computer? Can we write a program to make a computer as much intelligent as a human being? Never to forget, a computer with its own intelligence (!) defeated the chess guru. Even keeping this incident (or accident), in my mind, my firm belief is, computers or machines will never get the same kind of intelligence as a human being possesses though it sounds too much pessimistic– *No and Never*. Well, this might be a wrong idea after a long time from now, but, it is still a

long-long way to go, a lot of challenges [2, 14, 15, 16] to trounce by the AI, CI or intelligent technologies researchers before proving this '*Wrong*'.

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