GREY : AN ALGORITHMIC MODEL OF THE BRAIN

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The paper takes a view of the currently used methodologies and theories being used to find out the nature and mechanism of information processing in the human brain. The weaknesses of some of the techniques are pointed out. The paper finally talks about the technique designed and followed by the author. This technique presents a computer implementable algorithmic model of the information processing in the human brain....

The human brain is roughly approximated to be consisting of about 10^{11} elementary units called 'neurons,' which are interconnected to each other in roughly 10^{15} connections called 'synapses.' The information density of the human brain, if we consider a single synapse as an ordinary binary switching element, comes out to be about 10,000 times that of the most powerful supercomputers. But the binary nature of the neuron is just an oversimplified assumption. Also, the processing rate in the brain fares miserably as compared to computers. It is estimated to be around ten billion times slower than that of computers. The total information content is also not very large (1). Inspite of that our brain makes us do functions which,so far, we have not been able to replicate on a computer. This complexity of the human brain makes it one of the most unexplainable mysteries of the nature. The behavioural properties like 'learning,' 'remembrance,' 'habit,' 'forgetfulness,' 'adaptability,' etc. are still not understood very well by the researchers. Many theories and models, both psychological and mathematical, have been proposed using newer and newer techniques like neural networks, genetic algorithms, etc., but almost all of them have not been much successful in comprehensively explaining the information processing mechanism of the (human) brain.

The research on brain can be broadly divided into three categories :

1. At the neuron level, neurobiologists are trying to understand the exact electro - bio - chemical nature of the reactions that take place whenever there is some information interchange.
2. At the interneural level, where the computer scientists alongwith neurobiologists and mathematicians are trying to find out the nature of such an efficient network of neurons.
3. At the topmost level of the brain, treating the brain as a sort of black box, and trying to find out the concepts behind information processing. Here we are least bothered of as to what exact physical, chemical, biological, and electrical actions are taking place inside the brain. We are only interested in knowing the

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mathematical manner in which the changes are taking place. In this area computer scientists are taking a lot of help from mathematicians, psychologists and behavioural analysts.

In this paper, I shall be concentrating on the third field. The most interesting characteristic of the brain which I have tried to analyse is its effortless ability in interpreting uncertain, incomplete, and probabilistic information. When we human beings communicate with each other, we use so many vague or fuzzy statements, but still we can understand almost all of them in most of the cases. How is it possible? Is there some part of our brain, unknown to us, which is exclusively dedicated for such a demanding task? We don't know the answer, biologically speaking. But a mathematical formulation can surely be carried out to understand the mathematics involved behind these things.

One of the earliest attempts towards understanding the natural language processing ability of human brain was performed by Joseph Weizenbaum of the Massachusetts Institute of Technology. It was a non - directive psychotherapy program called as ELIZA. It was a great attempt towards understanding the information processing in the brain, but the program concentrated only on the syntactic part of the problem, and not on the semantic part of it. That is, one could not know if the program was really understanding the things the way we human beings do. After some time it would start repeating its questions, imitating the behaviour of a person with limited knowledge of some foreign language in that country, and that too not affected by experiences. There was no learning in the program. Basically, these type of programs involved representations that were usually very simple , and either represented only a very superficial analysis of the sentences, or could represent knowledge in a very semantically constrained world, such as blocks world (2). Same was the fate of some programs developed for translation of text written in one language to other. Cases of 'Out of sight, out of mind' getting translated into Chinese as 'Invisible, idiot,' or 'The spirit is willing, but the flesh is weak' getting translated into Russian as 'The vodka is good, but the meat is rotten' are very common in these programs (3). The basic problem with these programs is that they work on standalone statements or words, whereas we human beings use these statements in reference to some other statement(s). To sum it all, these models could not be used to imitate the communication skills of the brain to a very great extent. Some methods and theories like those based on neural networks and genetic algorithms could explain some of the behavioural characteristics like 'learning,' 'habit,' 'adaptability,' etc. to a very limited extent. Some theories put forward by psychologists are too abstract in nature and hence are of no use to brain researchers. Right now, inspite of having so many theories on evolution of intelligence on brain, on the development of communication skills, and on behavioural characteristics of the brain, we don't have a single theory comprehensive enough to explain these properties of brain.

I have designed and subsequently implemented one algorithm called GREY (a name obvious enough to be) to imitate the behavioural characteristics of brain like 'learning,' 'habit,' 'forgetfulness,' 'adaptability,' etc. It differs from other models because it is based on the Theory of Fuzzy Sets proposed by Lotfi A. Zadeh of Berkley University in 1965. Based on the fuzzy set theory I have assumed the neurons, if not all then atleast some of them, are not binary switching elements, but 'fuzzy switching elements.' That is, they are not necessarily excited whenever the information is all correct or all wrong. Also the parameters, in the begining atleast, are all defined by possibity distributions. As the parameters are used, our learning ability updates this possibility distribution and changes shape of the distribution curve.

The model GREY can be algorithmically described as follows:

1. Create an environment with some parameters. Pre-assign these parameters with some default values. The assignment may be fuzzy or non-fuzzy depending on the need and the scope of the problem. Assign the strengths to all the parameters as some possibility distribution, such as the standard s-membership function distribution.
2. Define some elementary commands in the environment which are, to the best possible, discrete and non-fuzzy.
3. Design an interpreter which can interprete the commands defined in step 2 in the machine language and can execute them.
4. Design the program for the given problem using these commands.
5. Define the tolerance levels for the results. Again, they can be fuzzily defined by a possibility distribution, or non-fuzzily defined by percentages, etc.
6. Repeat the following steps till step 9.
7. Execute the program.
8. Compare the results against pre-defined tolerance levels. If the obtained results are within tolerance levels, go to step 11.
9. Use genetic algorithm techniques, in particular punish-or-reward strategy for the parameter adjustments. They can be changed in any way, but the results of the random method more closely resemble to those observed in nature. Change some parameter randomly, retaining the old value. If there is an improvement in the obtained result, go in that direction, discarding the old values. Do it for all the parameters, and their combinations as well. As far as genetic operators are concerned, we are using only mutations, and simulated annealing. Keep a record of all the paremeters that were changed during the iteration.
10. Increment the 'strength' of a paremeter by operating CONC operator on its possibility distribution if it has been used in the loop, else for all parameters, decrease it by DIL operator.

    The concept of strength has been used to simulate the concepts of learning, habit, and forgetfulness. Depending on the scope of the problem and its requirements, the threshold values can be decided to make a parameter as a habit, or a thing of past and may be subsequently deleted. But this again depends on the type of problem.
11. If a better result is wanted, fine tune all the parameters that were changed during the iteration.
12. End.

This algorithm is not something new. Basically, I have tried to blend four very important techniques viz. Genetic Algorithms, Neural Networks, Theory of Probability, and the Fuzzy Set Theory.

I have used this algorithm to simulate a problem, which I have called 'Blind Walk.' All of us have seen a blind man walking using a stick as a forward sensor. Now, a suppose blind man knows that there is an edge about ten yards ahead in the direction in which he walking. He has an information described in fuzzy terms only. He is supposed to just reach the edge in finite amount of time. Further, he is not allowed to retrace his path. How will he walk? Most probably, he will firstly take some comfortable four or five or maybe six steps of one yard each (which is the maximum allowed step size), after that he may realize that he quite close to his destination, and he may reduce his step size by say 50%, and continue walking. He will go on walking, and decreasing his step size in such a fashion that in finite amount of time, he just manages to reach the edge, after which he will stop. How is this sort of 'multi-step iteration' taking place in his mind ? We don't know, but the algorithm presented above can be used very efficiently to simulate such a motion.

The algorithm works on the basic assumption that neurons are not strictly binary switching elements, and hence the concepts are not defined by binomial distribution, but by fuzzily defined possibility distributions. In fact, this is one of the most important weaknesses of most of the current techniques being used. The assumption about the binary nature of neurons makes us rely on the conventional set theory, and it can almost be said without a proof that the behavioural characteristics of human beings can't be modelled using the conventional set theory. So, this algorithm basically presents a neural network technique, in which the neurons are fuzzy switching elements, training being imparted using the genetic algorithm techniques.

The implementation work is still not complete by any means, and is going on. The author hopes to present a more discrete approach to the problem within a year or so, when the implementation is expected to finish.

CONCLUSIONS

I have tried to tackle the problem in a different way using the concept of possibility distribution in neurons. The paper still leaves most of the questions unanswered about the behavioural properties of the brain, like 'Short Term Memory,' etc.

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