

# Machines (non-human) and thinking: can they coexist?

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*The present article addresses the question of co-existence of non-human machines and the process of thinking. By drawing rationale and cues from earlier research efforts, a new scheme of thought for storage of learned knowledge – as an upper envelope – followed by subsequent re-construction of brain's neural network, is proposed. This designed concept is then put into perspective by providing arguments from the existing research, thereby making a small effort towards realizing machines that may be conscious.*

**Keywords:** Artificial intelligence, coexistence, knowledge, machines.

EVER since the advent of computers, more since the seminal question posed by Alan Turing, and at least since last six decades, mankind has strived for the quest of building machines that can emulate the power of human brain. The reason for such an effort rests in the fact that the quintessential ease with which our brain performs many a complex task, is indeed a marvel to try to emulate. Researchers like Alan Turing, Marvin Minsky, John Searle, and Churchlands to name a few have worked extensively in topics as broad as 'emotion machines' and can computers think? Very recently lot of progress has taken place in neuromorphic computing, which essentially tries to design computer systems, which can handle those tasks with relative ease that modern day computers find challenging. Another noteworthy development in recent past is in the area of deep learning. This field is indeed fascinating from the point of view of research in learning systems. In brief, the reason for saying so can be stated as deep learning software attempts to mimic the activities in layers of neuron in neurocortex, essentially the area where thinking occurs in brain. In deep learning it is possible to learn patterns in digital representation of sound, images and host of other data. Another equally important development of nearly half a decade is the emergence of big data and its analysis. This area focusses on extraction of meaningful pieces of information from significantly high volume and/or very high dimensional data.

The effort towards building a system which can mimic human beings for the advanced cognitive task of thinking needs development on multiple fronts. These are in the areas of hardware-based processing, data handling, pattern recognition, visualization, artificial and computa-

tional intelligence, system-on-chip, to name a few. The realization that artificial systems can be engaged for tasks that can be categorized as 'higher cognitive abilities of humans' like thinking, was present in researchers mind for more than half a century. Certain interesting developments that happened in period of time are highlighted here for a better understanding of the event chronology, that propels us to again revisit the proposal, 'Can machines think?'. For the impact of these events interested readers may refer to refs 1–5. Before concluding this paragraph it is significant to mention that our understanding of brain, its structure and its functions, along with human behaviour and emotions in an integrated manner should be the focal point of research which attempts anything similar to the title of this article.

In 1958, John von Neuman while writing the book 'Computer and Brain', mentioned that a deeper and detailed understanding of human nervous system may change the way we look at mathematics and logic, primarily from the viewpoint of how it is deployed for varieties of computational tasks. The pioneer of computer was perhaps suggesting an alternative way in which computing or symbol manipulation might take place in human nervous system. Carver Mead, in an outstanding work in 1989, published about a silicon chip designed to mimic visual processing in retina<sup>6</sup>. This particular piece of work again suggests that scientists and researchers were engaged in design and development of computing systems that looked to hire ideas and notions from the way it is done naturally. This work was also significant because it signalled an effort to capture the inputs from sensory organs for on-chip information processing.

Having discussed certain essential ideas that seem important in modern context, I now delve into an idea that revolves around intermixing and inter-playing the art of science and the science of art within each other to form the science and art of everything – perhaps the smart way

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of doing things. To the best of my understanding, smart ways stem from the thought process to design and deliver an idea, as a usable product to the society at large, perhaps in the most optimized sense. The question is ‘who thinks? Is it man or the machine?’ Is a machine capable of creating a relevant problem and posing a possible solution to it on its own, which man is capable of. These are indeed questions which need many complex entities like consciousness, emotion, feelings and self-awareness, etc. to be realized in computational domain<sup>1</sup> before an answer to this may be sought for. Having said this, it is important to understand whether spending time before replying a question amounts to thinking or not. For example let us look at two situations well discussed and debated:

1. Man/machine asked to identify a face in a crowd,
2. Man/machine asked to add two 20-digit numbers.

We are well aware of the performance of both the entities respectively in the aforesaid two situations. Now the interesting issue is to discuss *whether the delay in response amounts to thinking or not?* We shall return to answer this question subsequently. Another issue which this article will try to address is the original question posed by Alan Turing, viz. *how to measure whether or not a computer can think?* To overcome this he proposed to ask if computer can successfully play an imitation game to fool the questioner, which according to him is something that can be measured.

### Related work

Searle<sup>2</sup> argued putting powerful conceptions about relationship between minds, brains and computers, and proposed simplified logical structures in terms of certain axioms and premises. I mention here the four premises for completeness and present the conclusion: (a) Brains cause minds; (b) Syntax is not sufficient for semantics; (c) Computer programs are entirely defined by their formal, or syntactical, structure and (d) Minds have mental contents; specifically, they have semantic contents. The generic conclusion drawn from Searle’s experiments may be summarized as: systemic manipulations of symbol systems guided by structured rules are grossly inadequate for conscious intelligence. The reason that can be attributed to his arguments is that it is difficult or perhaps impossible to generate real semantics from syntactic representations. Alan Turing<sup>3</sup> was the originator of the question ‘can machines think?’ He went on to discuss questions like (a) What is thinking; (b) What kind of things can think? (c) How can we tell that if something can think? He went on to analyse that the real question deals with figuring out whether something is thinking or not. In fact this is the question posed by us in the previous section and the paper proposes a reasonable answer for the same.

Turing went on to offer a functional definition of thinking, stating that a thing thinks if it meets the same behavioural criteria as do the paradigm cases of thinking things. According to my understanding the fundamental difference between Turing and Searle is the way they diverged on the behavioural aspect of thinking and that of consciousness. Searle perhaps was ascertaining a non-behavioural test for consciousness whereas Turing pointed at the congruency of action of a thinking machine with that of a human being.

Another interesting work is by Churchland and Churchland<sup>4</sup> wherein they clearly bring out the necessary conditions of a machine to think. They point out two important results in computational theory, namely (a) Church’s thesis states that every effectively computable function is recursively computable, and (b) Turing demonstrates that any recursively computable function can be computed in finite time, by a maximally simple sort of symbol manipulating machine. These machines are known as universal Turing Machines. Indeed their work has much deeper comments on Searle’s Chinese room experiment vis-à-vis the conclusions drawn by Searle from his own experiments. There is an interesting and deliberately manufactured parallel to Searle’s argument and thought experiment<sup>4</sup>. Churchland and Churchland<sup>4</sup> point out that it is perhaps inappropriate to say that rule based symbol manipulation can never embed within itself semantic processes responsible for the outwardly rule base. Churchlands further argue that human beings in general only have broad common sense understanding of the semantic and cognitive phenomenon, which they handle everyday apparently by following certain rule manipulations. They discussed the functional architectures of the modern day symbol manipulation machines<sup>4</sup>, which they strongly claimed as the wrong architecture for designing and realizing machines that could eventually think. They go on to discuss that human brain is a computer which has distinctively different style, and is capable of computing functions of great complexity, but computability trick of brain is not perhaps the way modern day artificial intelligence (AI) does. The authors argue that non-incorporation of behavioural pattern of conventional symbol manipulating machines might be an imposing impediment in design and development of machines that is consciously intelligent and is perhaps capable of thinking<sup>4</sup>.

In the last paragraph of this section I briefly present the seminal and classic work of Marvin Minsky<sup>1</sup>, where the author pondered and discussed many fundamental questions such as: (a) Could computers be creative; (b) Can computers choose their own problem? (c) Could a computer really understand anything? (d) Can a computer be aware of itself? These are only a few of the many that are discussed to present a clear perspective of AI, machines, humans, mind and the process of thinking thereby being conscious. The author presents that the structures and

processes that deserved to be called ‘self’ and ‘awareness’ were very complicated concept networks: he expressed his concerns that the real picture about those networks is different from what we currently presumed. In the words of Marvin Minsky – ‘A computer cannot do (xxx), because all a computer can do is execute incredibly intricate processes, perhaps millions at a time, while constructing elaborately interactive structures on the basis of almost unimaginably ramified networks of interrelated fragments of knowledge.’ The author argues that people reject the idea of computational theory of thinking, thereby denying minds to machines, however, there is potentially no better option that one may have except denial of the notion of conscious machine. He also states that modern day computer programs are just too specialized to handle anything that is as complicated as theory of thinking.

The most significant point that emerges is that none of the authors seems to deny the co-existence of machine (non-human) and thinking, however, all of them point out the inadequacy of modern day computer programs, the way data, information and knowledge is represented, and perhaps the way we apparently visualize and program the mind and brain interaction. We now discuss a possible thought that may shed some light on how we can design machines that may eventually be capable to think!

### Proposed strategy

In the first part of our analysis, the human mind and brain is considered as a system that performs astonishingly complex tasks with seamless ease. The brain is visualized as an entity that has simple processing elements, called neurons; it has synapses, synaptic junctions and axon to carry signals between neurons. Therefore, crudely speaking brain is the hardware that facilitates the tasks like computations, representations, indexation, etc. Mind may be thought of as functional and operational aspect of brain that is ready to fire at all times. Mind has states that are capable of storing information and knowledge, albeit at a very abstract or coarse level, that is sufficient to instruct the hardware in brain to perform computational tasks as and when required. On an ambitious note I shall draw analogy of brain and mind with mass and energy. Following Einstein’s general theory of relativity, energy and mass are inter-convertible. In that sense I propose to look at mind and brain. Energy has various states, so the mind may also have similar states. The nature of states of energy, vis-à-vis that of mind’s, is a topic of further research which needs to be dealt with separately. With this understanding let us try to build the notion of thinking-from Turing’s perspective of ‘measurability of thinking’.

Mind interacts with environment to process a query. The query can be a concept to be dealt with or a stimulus from multiple sources. This prepares the relevant inputs necessary for the brain to process and produce result as

the desired output or its response. However, there is a caveat. If based on inputs, requisite mind states can be retrieved, and then we say that the answer is given in a flash, as if thinking is not there like the way a machine (computer) adds two 20-digit numbers but humans take time. We are not concluding anything about thinking here, but will return to it subsequently. In the event that mind states are not sufficient to answer the query, as very fundamental aspects of any subject are stored as mind states, we shall discuss about these fundamental aspects in a succeeding paragraph, then in these events mind engages in re-construction of the original brain network that was responsible for learning to encapsulate these mind states for a specific nature of tasks. This autonomous re-construction of brain network along with its topology, that takes a finite time, constitutes the process of thinking. This re-constructed network is capable of producing generalized results – as we know neural networks generalize from the inputs presented to it – hence able to overcome the possibility of using structured rules as a means to produce the outcome. Now the question is: how can we measure this process of thinking?

To answer this question, it is prudent to bring out details about the kind of information that is stored in mind states – the very fundamental aspects of learning. To take examples from our day-to-day activities, the small things like  $1 + 1 = 2$ ;  $2 \times 3 = 2 + 2 + 2 = 6$ ; associations; very abstract concepts; correlations and so on. A significant point to note is that these mind states store those information only in that details, which is enough to guide the process of re-construction of brain networks. For tasks like pattern classification – the mind states may store information like (a) type of network used; (b) number of layers (if any); (c) number of nodes used in each layer, etc. The possibility of storing information about emotional states of the learner is also there. All this storage in mind states actually take place once the process of learning is accomplished. The abstracted knowledge about a specific task is probably necessary and sufficient for the mind to instruct brain for re-construction of a similar network when a query is received. Once a query is encountered, the mind retrieves the abstracted knowledge or perhaps all the abstracted knowledge of similar nature, and guides the brain neurons to re-construct a network or series of networks, that stems from the cumulative abstracted knowledge stored in the mind states. The original network that learned the task if represented by  $N_o$  and the re-constructed network that answers the query if represented by  $N_r$ , then the difference between  $N_r$  and  $N_o$  gives us a quantifiable *measure of thinking*. If, at all,  $N_r$  and  $N_o$  are equal, then, in that case *measure of thinking* may be defined as:  $N_o^{\|N_r - N_o\|}$ .

Before concluding this section, we shall revisit the two questions posed earlier and present the answers in the current context. The first question pertains to the identification of face by man and machine in a crowd. The ease

with which humans perform this task relates to storage of information/knowledge in the mind states. Perhaps, more often than not, the re-construction of brain network is not required, pointing at a radically different way in which the process of computation takes place in our brain's designated region<sup>1-5</sup>. As far as machine is concerned for the task of face recognition, normally the execution of the task is undertaken by designing a suitable classifier. This article suggests a new proposal by capturing a kind of meta-data or suitably abstracted information layer to guide the re-construction of neuronal architecture for the task of classification at an operational level. Further, the design and choice of features is motivated by our current knowledge about AI and pattern recognition. This should motivate researchers to look at the computational schemes of modern day systems.

Man/machine asked to add two 20-digit numbers. The machine performs the task in a whisker, not because it satisfies a formulation like the one proposed in this article, but due to its sheer capability of processing, its clock speed, etc. In computers we have registers to add numbers, multiply them and perform other mathematical operations. Therefore, everything that we do originates from the learned knowledge of mathematics and perhaps that is genesis of our thinking process. However, when a man is asked to perform the task of addition, the invoking of mind states takes place, and a re-constructed network is deployed repeatedly to add the numbers. Therefore, going by this argument we now state that a man thinks but machine, in current form, does not think while performing addition of two 20-digit numbers.

Another example will exemplify our argument. Suppose we need to multiply 75 with 75. If a person multiplies the numbers by conventional method then he takes a finite time, say  $t_0$ . Now consider a rule like this: (a) multiply the digit in the units place; (b) increment the digit in the tens place by 1 and multiply it by the original digit in the tens place and concatenate the two numbers to obtain the result. Let us say the time taken by this method is  $t_1$ . It can clearly be seen that  $t_0 > t_1$ . The point that I want to make is suppose there is a mechanism to capture these rules during learning phase and subsequently store as mind states, then we obtain a substantial gain in delivery of results when a query is posed. Therefore, we emphasize that the more efficient is the information/knowledge captured and stored in mind states, the better is the performance in terms of both accuracy and speed. Clearly we can state now that man performs thinking whereas the machine does not.

Going back to the first problem again from the perspective of machine, when we relook at the issue of extracting mind states for a given query input, we encounter that direct extraction of mind states is not feasible as patterns prepared for input cannot be just summed up or multiplied at the register level to extract the result. Therefore, it becomes mandatory to re-construct the 'brain's

neural network' (this is what perhaps man does very efficiently, whose modalities are not yet known). Here this process of re-construction needs a focused understanding. This problem is not similar to the original learning problem because after completing the learning phase, mind states are stored and retrieved during processing of a query. It is here, perhaps, our mind applies its intelligence to re-construct the network for answering the query based on all or some of its previous knowledge which appears in various mind states. Therefore, we humans generalize fairly accurately and machines fail to do so. This is where, as discussed earlier, the resultant network may not be identical to the network that was created due to the process of learning. Significantly, if during learning, we understand and focus on generalities and not specifics (unfortunately the way mathematics does), as mentioned with the multiplication example, we are more likely to build a network closer to the learning network. This will facilitate machines to perform enormously complex tasks with relative ease as the thinking process in machines will tend to mature.

Before concluding this section it is important to point out that, during learning phase, content is in focus and context gets embedded and perhaps gets transferred to the mind states. On the contrary, while re-construction, context is in focus and meaningful content gets created. Perhaps this is the way in which both top-down and bottom-up (both art and science) approaches are intermixed in man's mind and brain system to make them smart creatures!

### Algorithmic thinking

In this section I sum up the scheme of things that have been proposed. In line with this let us define thinking. By *thinking* we mean the following: 'To be able to dwell in a space of discovered areas, for the purpose of uncovering new frontiers for a given context, situation, task, wherein tools used for overall discovery/uncovering are not unknown, but their results are, in an autonomous manner.' Therefore, the process of thinking is goal directed that requires constant and fast navigation between tools used for discovery, along with context switching between states of mind that may or may not always lead to the correct/desired result. To sum up, it is mind, and not brain, that engages itself for the process of thinking that utilizes the information and knowledge stored in the mind states, along with utilizing neuronal connections of brain to retrieve, recollect, polarize and assimilate the stored data, information and knowledge in distributed connections of brain's circuitry to motor the process of thinking.

To this end, one may propose to inquire whether it is possible to think beyond the span of knowledge of oneself, or for that matter, if machines have a structured mind as discussed in this article, then can it think beyond the knowledge spanned by its state vectors taken

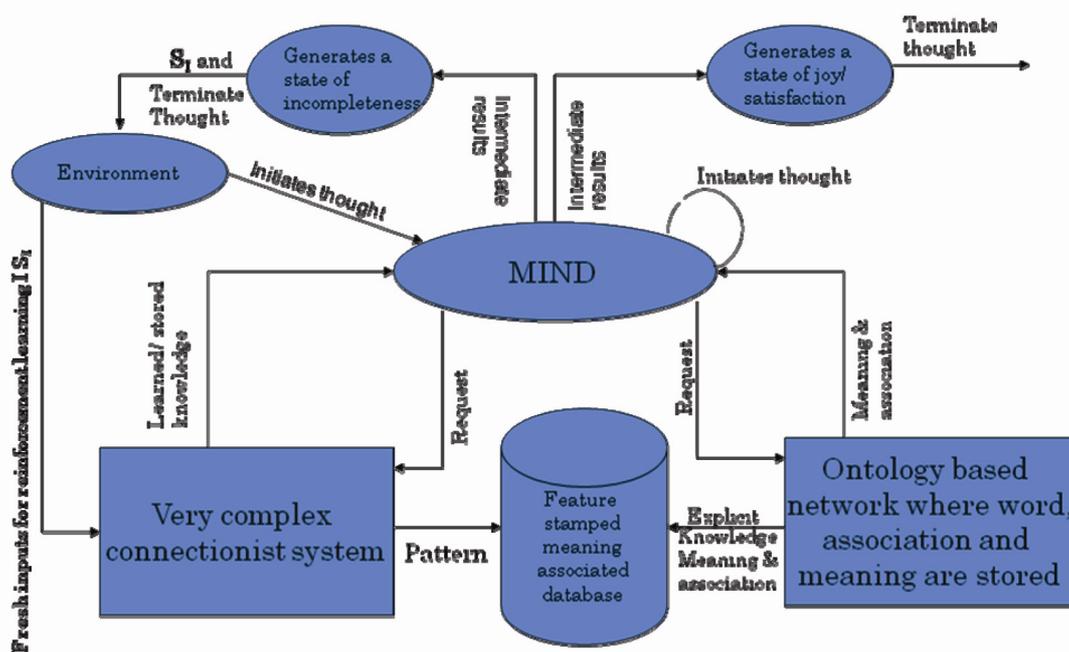


Figure 1. A schematic of a machine that may think

together. The answer to this is probably ‘No’; however, it is perfectly possible to learn new things to modify the state space of mind to broaden the horizon of thinking. Now we present the role of ‘meaning’ in thinking. One of the necessary and sufficient conditions for the process of thinking to initiate, continue, and finally to terminate is to identify the meaning of what is to be uncovered/ discovered. It is therefore mandatory to understand the meaning of all intermediate results. Meaning is not what we humans mean and make a forceful attempt for the machine to mean the same. Here ‘meaning’ is referred to in the sense of a structured, may be grammatical, representation of basic entities and certain repercussions of assuming basic entities the way it is assumed.

Now we discuss and present the question that is the title of this paper. Can we devise machines that think? Summarizing the understanding developed so far, we now delve into the idea of ‘algorithmic thinking’ – which is a state/sequence of states of mind that engages with the existing knowledge by properly identifying the meaning of what is being thought, which terminates from internal stimuli of joy/satisfaction for being able to obtain the correct/desired result. Process of thinking also terminates from internal stimuli of incompleteness that desired results are not possible to be realized, thereby invoking an environment for further learning.

Process of thinking may also terminate from an internal stimulus of void, wherein the thought process is suddenly and abruptly terminated without any further necessary action. Therefore, we define mind as: ‘Mind is a set of states where flexibility to generate very large number of

states is permissible while performing the task of learning. States may be emotional, computational, linguistic, logical, etc. in nature’.

Figure 1 presents a broad schematic of a machine that may eventually think.

### Conclusion and discussion

In this section I shall try to place the work in perspective of the current research efforts. Most importantly I wish to draw the attention towards the classic work of Minsky<sup>1</sup>. Under the section ‘Could a computer be conscious?’, he highlights the fact that if humans are so imperfect at self-explanation, then there is no reason why machines cannot be made better than us in finding out about themselves. The argument is extended to make the machine understand that inner information. To quote Minsky, ‘It seems to me that no robot could safely undertake any very complex, long-range task, unless it had at least a little “insight” into its own dispositions and abilities’. Let us analyse this point in our perspective. The kind of information/knowledge that the mind (attached to machine, either human or non-human) encapsulates in the states of mind after the learning phase, can be looked upon as an upper envelope of the learned knowledge – which Minsky mentions as little ‘insights’ into its own dispositions and abilities.

Minsky also states ‘Furthermore, if it is to be able to learn new ways to solve hard, new kinds of problems, it may need, again, at least, a simplified idea of how it

already solves easier, older problems'. This fact was exemplified when we discussed and presented the example of how one could speed up multiplication of two numbers like  $75 \times 75$  – by capturing the right kind of knowledge in the mind states. We argue that the storage of upper envelope of gained knowledge during the learning phase is good enough for the mind to initiate multiple times repeat action to answer queries of similar nature.

The interesting part of design following idea presented in this article is, the mind states are too loose and generic in nature. In this way, though, one may perform a learning task of specific nature by deploying either numeric, linguistic, or emotional parameters as variable, the mind slowly, with passage of time, and keeping with the previous learning experiences, deploys simultaneous networks that emanate from varieties of states to answer a given query. That is why, perhaps, we encounter such novel and beautiful results every time, and more from our children, whose mind states are not yet mature enough. Lastly, to quote again from Minsky<sup>1</sup>, 'It seems that common sense thinking needs a greater variety of different kinds of knowledge, and needs different kinds of processes'. Greater variety of different kinds of knowledge gets embedded in varieties of mind state, albeit for a single task, and an intelligent mind chooses some or the entire mind state's envelopes to re-construct the brain network required for answering a specific query.

Churchland and Churchland<sup>4</sup> mention an interesting point which facilitated the core idea of this work. They state 'First, the physical material of any symbol manipulating machine has nothing essential to do with what function it computes. Second, the engineering details of any machine's functional architecture are also irrelevant, since different architectures running quite different programs can still be computing the same input–output function'. Here, in our scheme of things, the mind states associated with a particular task having a fixed input–output function can be many, for example numeric, linguistic and emotional. Therefore, to answer a specific query, the mind invokes its states and goes on to re-construct either all or some of the neural connectivity, as separate networks, to produce the desired result as the

*response of mind-brain interaction*. The scheme of things, proposed in this paper, does not manipulate symbol according to structure-sensitive rules, but symbols are actually processed through the re-constructed brain networks, essentially guided by mind's knowledge envelope, thereby embedding generalization capabilities seen in natural systems. I believe that capturing varieties of mind states for a given problem (as large number of sensor processing devices are now available) may ultimately produce similar cognitive states and performance found in human being. The presence of multiple mind states for the same input/output representation and their cumulative role in final response may be comparable to *society of mind* concept of Minsky<sup>5</sup>.

Lastly, I would like to comment on Turing test which states 'a machine passes the test of conscious intelligence if and only if the responses given by the machine cannot be discriminated from the typewritten responses of a real intelligent person'. Perhaps the methodology that is proposed in this article need not match the answer, as Minsky states – those artificial creatures might have richer inner lives than people do<sup>1</sup> – therefore, the resultant network structure matching for two cases is a fit enough measure for the process of *thinking by man and machine*.

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