Frank Rosenblatt, Alan M. Turing, Connectionism, and Artificial Intelligence

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Abstract: Dr. Frank Rosenblatt is commonly associated with Connectionism, an area of cognitive science, which applies Artificial Neural Networks in an effort to explain aspects of human intelligence. Other notable connectionists include Warren McCulloch, Walter Pitts, and Donald Hebb, but it is Alan Matheson Turing, a man of unique insight and great misunderstanding, who is noticeably absent from this list. He is commonly associated with the development of the digital computer, employing his paper tape Universal Turing Machine. There are many who associate him with providing the foundation for defining Artificial Intelligence, specifically the development of the Turing Test as the standard to be met in determining if a machine exhibits intelligence. His contribution to AI goes beyond his test, laying down the foundation of Connectionism, providing insight into and supporting later contributions to the key models of Perceptrons, Artificial Neural Networks and the Hierarchical Temporal Memory model.

Introduction

The dawn of Connectionist Theory is commonly traced back to McCulloch and Pitts and their model of the Neuron. Further strength was added upon the publication of Donald O. Hebb’s influential book The Organization of Behavior (1949) [19], the source of the Hebbian approach to neural learning studied in connectionism today. The contribution to connectionism by Rumelhart, McClelland and the PDP Group [17, 18] cannot be minimized, yet all of them show no awareness of Turing’s early contribution to the field.

It was Frank Rosenblatt who in 1957 began looking at the McCulloch and Pitts [20] model of the neuron and started investigating neural networks. From his work came a new model he called the “perceptron”. Although perceptrons differed only slightly from previous neural networks, Rosenblatt made major contributions to the field through his experimental investigations of the properties of perceptrons (using computer simulations), and through his detailed mathematical analyses, basing the perceptron model on probability theory rather than on symbolic logic. He was influenced by Hebb’s concepts and was the first to associate the term “connectionist” with artificial neural networks. It was in 1958 when Rosenblatt provided a definition to the theoretical basis of connectionism in his statement, “stored information takes the form of new connections, or transmission channels in the nervous system (or the creation of conditions which are functionally equivalent to new connections)” [21, 22].

Dr. Rosenblatt was not primarily interested with the invention of devices for artificial intelligence, but rather with investigating the physical structures and neurodynamic principles related to “natural intelligence” [22]. He believed the perceptron was first and foremost a brain model, not an invention for pattern recognition. Although, never brought to its maturity, the perceptron plays a vital role in artificial intelligence and in connectionist theory. By his own admission, Rosenblatt did not believe the model was complete and summed up perceptrons in this passage from his 1962 book (page 28): "Perceptrons are not intended to serve as detailed copies of any actual nervous system. They're..."
simplified networks, designed to permit the study of lawful relationships between the organization of a nerve net, the organization of its environment, and the 'psychological' performances of which it is capable. Perceptrons might actually correspond to parts of more extended networks and biological systems; in this case, the results obtained will be directly applicable. More likely they represent extreme simplifications of the central nervous system, in which some properties are exaggerated and others suppressed. In this case, successive perturbation and refinements of the system may yield a closer approximation.[22] Dr. Rosenblatt’s contribution to Artificial Intelligence, Connectionism and in providing the foundation for Neural Nets and the HTM Model are significant, but he too was unaware of Turing’s early contributions.

**In the Beginning...**

The mid to late 1950s is often looked upon as the beginning of artificial intelligence. This, unfortunately, is incorrect. History, by way of discovery and re-discovery of the writings of Dr. Alan M. Turing, places artificial intelligence’s true origins to approximately 1950, and possibly as early as 1941. To most people, it was Turing’s article entitled *Computing Machinery and Intelligence* [1] which affords him his fame, but this is only part of Turing’s contributions to AI. The significance of this paper could not have been anticipated at time of its publication, yet its impact on artificial intelligence cannot be disputed. Within this paper, Turing poses the question, “Can Machines Think?”

To determine the answer to this question, he provides the reader with a “game” which first takes place between an interrogator, a man and a woman. These three individuals are separated from each other. The interrogator can ask questions of either of these individuals via “teletype” interface. The man will attempt to convince the interrogator he is the woman and the woman will be truthful. The objective is for the interrogator to correctly conclude who is the man and who is the woman. Turing now alters this game and replaces the man or the woman with a machine. It is now the objective of the interrogator to differentiate between the machine and the human. This is the basis of the Turing Test, a test integrally linked with answering the question he poses and for determining machine intelligence. Additional details shall not be presented, as it is best for one to read the original article.

Although his famous paper was published in 1950, Turing was harboring thoughts of machine intelligence as early as 1941 according to Donald Michie [2]. Michie remembers Turing would talk about the possibility of computing machines (1) learning from experience and (2) solving problems by means of searching through the space of possible solutions [2]. He was also attempting to make a comparison between a digital computer and the human brain. In a series of broadcast lectures, one given in May of 1951, Turing provided some additional insight into what he was thinking. In reviewing Turing’s typescript, it was found he believed digital computers could be used in such a manner they could appropriately be described as brains. He continues by saying, “although digital computers might be programmed to behave like brains, we do not at present (1951) know how this should be done. As to whether we will or will not eventually succeed in finding such a program, I (Turing), personally am inclined to believe that such a program will be found. Our main problem is how to program a machine to imitate the brain, or as we might say more briefly, if less accurately, to think [3-5]”.

Turing’s level of understanding of intelligence and artificial intelligence was far more advanced than previously understood, specifically in how we learn. It was Turing’s [4] understanding, in trying to imitate an adult human mind, we should consider three issues: the initial state of the mind, the education it has been subject to, and the other experiences it has been subject to (that cannot be described as education). His final thoughts show we should try to create a computational model a child’s mind and then “educate” it to obtain the model of the adult brain. It would difficult not to see the correlation to perceptrons, neural networks and especially to the hierarchical temporal memory model.

In the ensuing years, there remained many unanswered questions concerning his vision of artificial intelligence, his views on intelligent
machinery and the continuous debate as to the meaning of the “Turing Test” in defining intelligence. There are arguments attempting to show the fallacy of Turing’s concept of machine intelligence, such that a machine would need to be conciseness (be aware of itself), but is this a valid argument? Maybe Turing was looking beyond a simple definition of machine intelligence, but was unable to complete his work due to his untimely departure from this Earth.

Some of his critics have found fault in the behavioral approach of the Turing Test [6]; French [7] discusses whether passing the Turing Test is a sufficient or a necessary condition for machine intelligence and he asks whether the test can be passed at all. Perhaps it is Hayes and Ford [8] who provided a more provoking concern in a moral objection concerned with the artificial constraints the setting imposes on the participants of the game and to express their inability to find a practical use for the Turing Test. They ask why we put forth so much effort to build a machine to imitate a human.

An analogy is sometimes made between artificial intelligence and artificial flight. As long as scientists and engineers tried to copy the flight apparatus of birds, artificial flight remained illusive. When they abandoned the attempt to mimic nature, but instead studied the basic principles of flight in non-natural systems, successful aircraft were developed. Thus, AI researchers should abandon the goal of imitating human intelligence and rather seek general principles of intelligence in non-human systems in order to perfect artificial intelligence [9], an avenue the memory-prediction model appears to pursue.

Individuals who consider themselves connectionists usually consider Hebb and Rosenblatt as the originators of their approach, but in fact both were preceded by Turing, who anticipated much of modern connectionism in his 1948 paper “Intelligent Machinery” (see Proudfoot and Copeland, [4, 10, 12]).

From his writings and other documents, it is conceivable Turing was the first person who considered building computing machines out of simple, neurons-like elements connected together into networks in a largely random manner, referred to by Turing as “unorganized machines”. His invented neural network was called a “B-type unorganized machine”, which consisted of artificial neurons and devices capable of modify the connections between them. His model was very different in that every neuron in the network executes the same logical operation of “not and” (NAND): the output is 1 if either of the inputs is 0. If the both inputs are 1, then the output is 0. Turing selected NAND because every other logical or Boolean operation can be accomplished by groups of NAND neurons [10, 11].

It was Turing’s contention machines [4, 10, 12] could be constructed which would simulate the behavior of the human mind very closely. He goes further by stating these machines “will make mistakes at times and at times they may make new and very interesting statements, and on the whole the output of them will be worth attention to the same sort of extent as the output of a human mind.[4]” He looked at the creation or development of such a machine as being akin to a child, which would be able to learn by experience, such that by starting with comparatively simple machine, and by subjecting it to a suitable range of ‘experiences’ transform in into one which was much more elaborate, and was able to deal with a far greater range of contingencies.

The idea that an initially unorganized neural network can be organized by means of “interference training” is undoubtedly the most significant aspect presented in this paper. With Turing’s model, the training process renders certain neural pathways effective and others ineffective. He anticipated the modern procedure of simulating neural networks and the training process by means of an ordinary digital computer [12]. This is considered the first manifesto of AI and in it Turing brilliantly introduced many of the concepts associated with neural networks, although, in some cases after the reinvention by others. One of these was the concept of “teaching” a network of artificial neurons to perform specific tasks.

Turing also claimed a proof (now lost) of the proposition that an initially unorganized Turing Net with sufficient neurons can be organized to
become a universal Turing machine with a given storage capacity [12]. This proof first opened up the possibility, noted by Turing, that the human cognitive system is a universal symbol-processor implemented in a neural network. However, Turing's own research on neural networks was carried out shortly before the first stored-program electronic computers became available. It was not until 1954 (the year of Turing's death) that Belmont Farley and Wesley Clark [13], working at MIT, succeeded in running the first computer simulations of small neural networks. Farley and Clark were able to train networks containing at most 128 neurons to recognize simple patterns.

Many involved in the early years of AI research, acknowledge the Turing Test was inspirational, but as knowledge was gained in what a machine is capable and not capable of doing; together with advances in neuroscience and in the understanding of brain function, some argue the Turing test should be consigned to history. As put so eloquently by Hayes and Ford, “The Turing test has a historical role in getting AI started, but it is now a burden to the field, damaging its public reputation and its won intellectual coherence. We must explicitly reject the Turing Test in order to find a more mature description of our goals; it is time to move it from the textbooks to the history books [8].”

It is unfortunate such a test has been so widely accepted and at the same time, so limiting in determining if a computer is capable of intelligence. Although Turning always used the term “machine”, we have advanced such the name “computer” is more appropriate. Turing never claimed in the first place that the ability to pass the Turing test is a necessary condition for intelligence. Turing indicates the point of the test is to determine whether or not a computer can “imitate a brain.” Turing made it clear that a machine might be intelligent and yet not pass his imitation game. If ‘machine intelligence’ is no longer an oxymoron, then one of Turing’s important predictions has come true.

Turing predicated in about 50 years’ time from the publication of his famous article, it will be possible to program computers to make them play the imitation game so well an average interrogator will not have more than 70 per cent chance of making the right identification after 5 minutes of questioning. As history has shown, we continue to fail.

The End of it All

Consider how we perceive intelligence. A problem is presented to a mathematician or scientist to solve. The problem was presented specifically to these individuals due to their field of expertise. The solution may require the application of a new method or formula and it is possible they may return an incorrect solution. It is also conceivable many attempts may be necessary before a solution is found, if a solution can be found. What is our perception of them, are they any less intelligent in light of making an error when attempting to obtain the solution to a problem? The answer is no, so why do we not apply the same standard or perception towards a machine, a computer? When given a problem, if the computer should return the incorrect solution, should we state that it does not have intelligence? Intelligent humans, even highly regarded, intelligent humans are not infallible; they make errors, yet we do not consider them any less intelligent when they do, so why not apply the same standard or perception to computing machinery when we attempt to determine machine intelligence.

Some authors offer the Turing test as a definition of intelligence: a computer is intelligent if and only if the test fails to distinguish it from a human being. However, Turing himself in fact pointed out that his test couldn’t provide a definition of intelligence. It is possible, he said, that a computer which ought to be described as intelligent, might nevertheless fail the test because it is not capable of successfully imitating a human being.

Jeff Hawkins [23, 25, 28] basic premise, as embodied by Hierarchical Temporal Memory Model, seems right: perceptual-memory-based predictions surely do play a fundamental role in intelligence and hence in brain structure and function. What does this mean? That an intelligent agent learns from experience and in particular builds up a model of the world by perception (not only of what is out there but of what actions achieve what results); and that this
experience is remembered and available virtually instantly for use in deciding what to expect next. In the opinion of Professor David Gelernter [14], software today can only cope with a smattering of the information processing problems our minds handle routinely, when we recognize faces or pick elements out of a large group based on visual cues, use common sense, understand the nuances of natural language or recognize what makes a musical instrument cadence final. Turing seemed to believe (sometimes) that consciousness was not central to thought, simulated or otherwise. A computer can add numbers but has no idea what ‘add’ means, what a ‘number’ is or what ‘arithmetic’ is for. Its actions are based on shapes, not meaning. Dr. Gelernter agrees with Searle’s Chinese room. But if we take the route Turing hinted at back in 1950, if we forget about consciousness and concentrate on the ‘process of thought’ there is every reason to believe that we can get AI back on track, and that AI can produce powerful software and show us important things about the human mind [14].

References


