
CSC: Classic Paper Review/Analysis

Title and Author

Title Computing Machinery and Intelligence

Author A. M. Turing

Summary/Hook

In this paper, Turing considers the possibility for there to exist an entity that can produce intelligent thought. He argues that, with the development of the digital computer and machine intelligence, it will someday be possible for a machine to think and learn in the ways that a human can. Turing poses the question, "Can machines think?" and he provides precise definitions for the terms "machine" and "think," offers a number of examples to clarify his thoughts, the most relevant to his question being his delineation of the "Imitation Game," and describes additional queries that arise when we consider such a modeling of human intellect. To further strengthen his argument, Turing dedicates a significant portion of his paper to contrary views and objections to this fundamental question, providing well-founded responses and considerations in favor of his view to each. It is also important to note that he recognizes where his refutations may have some limitations, which further supports his argument and his understanding of the complicated nature of machine intelligence. Turing's claims remain controversial to this day, as some thinkers are not entirely convinced that it is possible for a machine to someday appropriately mimic the multifarious and complex undertakings of the human mind (i.e.- consciousness, emotion, subjective experience, perception, planning and prioritization, creativity, decision making, contextual influences to problem solving, etc.).

Knowledge Relating to the Cognitive Science Program Learning Outcomes

1. Formal Systems and Theories of Computation

A digital computer can usually be regarded as consisting of three parts: (i) Store. (ii) Executive unit. (iii) Control. The store is a store of information, and corresponds to the human computer's paper, whether this is the paper on which he does his calculations or that on which his book of rules is printed. In so far as the human computer does calculations in his head a part of the store will correspond to his memory. The executive unit is the part which carries out the various individual operations involved in a calculation. What these individual operations are will vary from machine to machine. Usually fairly lengthy operations can be done such as "Multiply 3540675445 by 7076345687" but in some machines only very simple ones such as "Write down 0" are possible. We have mentioned that the "book of rules" supplied to the computer is replaced in the machine by a part of the store. It is then called the "table of instructions." It is the duty of the

control to see that these instructions are obeyed correctly and in the right order. The control is so constructed that this necessarily happens.

2. Symbol Systems

The digital computers considered in the last section may be classified amongst the "discrete-state machines." These are the machines which move by sudden jumps or clicks from one quite definite state to another. These states are sufficiently different for the possibility of confusion between them to be ignored. Strictly speaking, there are no such machines. Everything really moves continuously. But there are many kinds of machine which can profitably be *thought of* as being discrete-state machines. For instance in considering the switches for a lighting system it is a convenient fiction that each switch must be definitely on or definitely off. There must be intermediate positions, but for most purposes we can forget about them. As an example of a discrete-state machine we might consider a wheel which clicks round through 120° once a second, but may be stopped by a lever which can be operated from outside; in addition a lamp is to light in one of the positions of the wheel. This machine could be described abstractly as follows. The internal state of the machine (which is described by the position of the wheel) may be q_1 , q_2 , or q_3 . There is an input signal i_0 or i_1 (position of lever). The internal state at any moment is determined by the last state and input signal according to the table.

3. Consciousness and Controversies

This argument is very well expressed in Professor Jefferson's Lister Oration for 1949, from which I quote. "Not until a machine can write a sonnet or compose a concerto because of thoughts and emotions felt, and not by the chance fall of symbols, could we agree that machine equals brain—that is, not only write it but know that it had written it. No mechanism could feel (and not merely artificially signal, an easy contrivance) pleasure at its successes, grief when its valves fuse, be warmed by flattery, be made miserable by its mistakes, be charmed by sex, be angry or depressed when it cannot get what it wants." This argument appears to be a denial of the validity of our test. According to the most extreme form of this view the only way by which one could be sure that a machine thinks is to be the machine and to feel oneself thinking. One could then describe these feelings to the world, but of course no one would be justified in taking any notice. Likewise according to this view the only way to know that a *man* thinks is to be that particular man. It is in fact the solipsist point of view. It may be the most logical view to hold but it makes communication of ideas difficult. A is liable to believe "A thinks but B does not" whilst B believes "B thinks but A does not." instead of arguing continually over this point it is usual to have the polite convention that everyone thinks.

4. Algorithms and Automata

Advances in engineering will have to be made too, but it seems unlikely that these will not be adequate for the requirements. Estimates of the storage capacity of the brain vary from 10^{10} to 10^{15} binary digits. I incline to the lower values and believe that only a very small fraction is used for the higher types of thinking. Most of it is probably used for the retention of visual impressions. I should be surprised if more than 10^9 was required for satisfactory playing of the imitation game, at any rate against a blind man. (Note: The capacity of the *Encyclopaedia Britannica*, 11th edition, is 2×10^9) A storage capacity of 10^7 , would be a very practicable possibility even by present

techniques. It is probably not necessary to increase the speed of operations of the machines at all. Parts of modern machines which can be regarded as analogs of nerve cells work about a thousand times faster than the latter. This should provide a "margin of safety" which could cover losses of speed arising in many ways. Our problem then is to find out how to programme these machines to play the game. At my present rate of working I produce about a thousand digits of program a day, so that about sixty workers, working steadily through the fifty years might accomplish the job, if nothing went into the wastepaper basket. Some more expeditious method seems desirable.

5. Psychological Investigations

We normally associate punishments and rewards with the teaching process. Some simple child machines can be constructed or programmed on this sort of principle. The machine has to be so constructed that events which shortly preceded the occurrence of a punishment signal are unlikely to be repeated, whereas a reward signal increased the probability of repetition of the events which led up to it. These definitions do not presuppose any feelings on the part of the machine. I have done some experiments with one such child machine, and succeeded in teaching it a few things, but the teaching method was too unorthodox for the experiment to be considered really successful. The use of punishments and rewards can at best be a part of the teaching process. Roughly speaking, if the teacher has no other means of communicating to the pupil, the amount of information which can reach him does not exceed the total number of rewards and punishments applied. By the time a child has learnt to repeat "Casabianca" he would probably feel very sore indeed, if the text could only be discovered by a "Twenty Questions" technique, every "NO" taking the form of a blow. It is necessary therefore to have some other "unemotional" channels of communication. If these are available it is possible to teach a machine by punishments and rewards to obey orders given in some language, *e.g.*, a symbolic language. These orders are to be transmitted through the "unemotional" channels. The use of this language will diminish greatly the number of punishments and rewards required.