ALAN TURING -
EINSTEIN OF COMPUTER SCIENCE

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ABSTRACT

Achievements of Alan Mathison Turing (AMT) in computer science and informatics resemble those of Albert Einstein in physics. Turing's contributions are presented through most important events and achievements, and in particular through the concept of hypercomputers. Several AI and human-intelligence related concepts are analyzed. A short text is devoted to Donald Michie, Turing's co-worker and contemporary, an honorary member of the Jozef Stefan Institute. Even though his centenary, Turing remains largely unknown to an average citizen of the world. An appeal for his full recognition is proposed.

1 INTRODUCTION

In Wikipedia, one finds: Alan Mathison Turing, (23 June 1912 – 7 June 1954), was a British mathematician and computer scientist. He invented a formalisation of the concepts of "algorithm" and "computation" with the Turing machine, which can be considered a model of a general purpose computer.

Upon Turing's centenary, all over the world there were events related to Alan Mathison Turing. There have already been lectures and publications about Turing in Slovenia, e.g. (Gams Turing lecture 2012, Gams Oz 2012).

Lectures about Turing typically highlight the following dates:

1912 – Turing's birth
1936 – publication of the Turing machine
1932-42 – Enigma decoded
1950 – the birth of AI, Turing test
1954 – Turing's death
2007 – death of Donald Michie
2009 – official rehabilitation
2012 – centenary

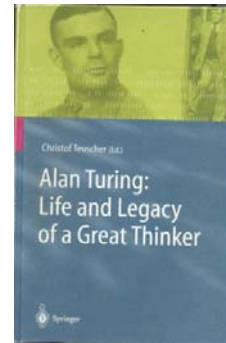Some of these dates and the related events will be analyzed in the next sessions.

Figure 1: One of the many books about Alan Turing.

2 IMPORTANT CONCEPTS

2.1. Turing machine, TM

In 1936 Turing published a paper about a Turing machine, also a universal Turing machine, and the halting problem. He was interested in undecidability of formal systems, as was his professor Hilbert. An undecidable problem is a decision problem for which it is impossible to construct a single algorithm that always leads to a correct yes/no answer. A decision problem is any arbitrary yes/no question on an infinite set of inputs.

Formally (Reiter 2012), a decision problem A is called decidable or effectively solvable if A is a recursive set. A problem is called partially decidable, semidecidable, solvable, or provable if A is a recursively enumerable set. Partially decidable problems and any other problems that are not decidable are called undecidable. In computability theory, the halting problem is to decide whether the program finishes running or will run forever given a description of a program and a finite input.
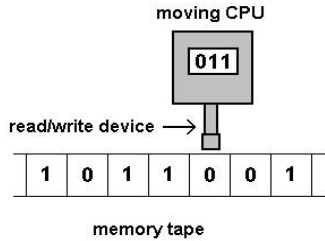
Figure 2: The Turing machine.

Alan Turing proved in 1936 that a general algorithm running on a Turing machine that solves the halting problem for all possible program-input pairs necessarily cannot exist by constructing a counterexample. Since there are algorithms (programs) that no other algorithm can decide whether it will stop or not, the halting problem is undecidable for Turing machines.

Gödel published his incompleteness theorems (Raguni 2012) already in 1931. A weaker form of his first incompleteness theorem is a consequence of the undecidability of the halting problem. This weaker form differs from the standard statement of the incompleteness theorem, meaning that the axiomatic system is a necessity if one wants to prove all true statements about natural numbers. To be a bit more specific, there are two issues: provability and truth. In the first case the issue is just about proving, in the second about being true but not provable. In both cases, in a formal system there are statements that are true and cannot be proven, even though there are sentences (algorithms, programs, theories), that cannot be proven regardless of their truth value (Bojadzijev 1999). Turing's contribution was in proving the concept in the computability, i.e. computer field.

In the process of proving the halting problem Turing introduced the Turing machine as presented in Figure 2. This simple and basic computing model represents the best ever known model of computing and also digital computers we use today. Theoreticians are quick to point out that the Turing machine needs a sufficiently long tape, i.e. data storage equivalent, and therefore computers are not true equivalents of Turing machine but rather finite automata (of huge kind), but the author of this paper finds this argument superficial. If the computer memory is big enough, then the difference is meaningless in all but the theoretical terms.

The essence is that the Turing-machine concept represents such a basic concept or a computing principle that it can be compared to the Einsteins' relativity principles. Indeed, both are neither axioms nor theorems, but computing mechanisms or principles, one describing digital or symbolic computers and the other time-space relations.

2.2. Hypercomputing

One would imagine that new, improved versions of computing mechanisms, i.e. advanced Turing machines, were invented since 1936. If models of computation are in principle »stronger« than the Turing machine, meaning that they can solve tasks that the Turing machine cannot, then such machines are called hypercomputers or super-Turing computational models. The second term usually denotes physically realizable mechanisms. These computing mechanisms include computation of non-Turing-computable functions, following super-recursive algorithms. The term "hypercomputation" was introduced by Copeland and Proudfoot (1999).

There are several issues often discussed in relation to the hypercomputing. One is the Church-Turing thesis (Wikipedia 2011). It states that any function that is algorithmically computable can be computed by a Turing machine. Hypercomputers compute functions that a Turing machine cannot, therefore are not computable in the Church-Turing sense. There are publications indicating that no physical machine can be designed to surpass the Turing machines, and that it is not possible to construct a counterproof. In other words, the hypercomputers ideas might be hypothetical in nature.

Several authors such as Roger Penrose (2002) oppose the notion that computers are as powerful as digital computers directly indicating that humans either possess

- Stronger mechanisms than Turing machines (hypercomputing, often proposed as some stronger semi-mental process) or
- Mechanisms that are not in principle stronger, but so different in practical computer terms that computers cannot compete with them under real-life circumstances. In other words, the human brain is not in principle stronger, but in reality stronger for the majority or the real-world tasks.

An example of a problem a Turing machine cannot solve is the halting problem. Some proposed hypercomputers can simulate the program for an infinite number of steps and tell the user whether or not the program halted. It is claimed by some authors that the halting problem can be solved by humans even though not using additional information which is known to enable solving the halting problem.
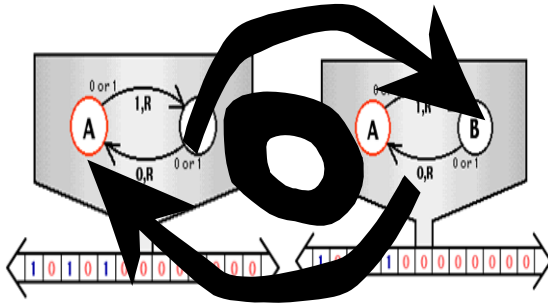
Figure 3: The Multiple Turing machine.

The author of this paper endorses the Multiple Turing Machine, as presented in Figure 3. Unlike multi-tape Turing machine it consists of two universal Turing machines, each writing on each other program at the same time getting information from the open outside world. It is based on the principle of multiple knowledge (Gams 2001). The weak version of the principle states that a sensibly integrated model (or computing mechanism) in general outperforms each single model constituting the basic set of models. The strong version of the principle states that real or human-level intelligence can be achieved only using the multiple algorithms applying the principle. Please note that multiplicity may or may not include parallelism; rather it resonates the interaction concept (Wegner 1997). The principle of multiple knowledge has several manifestations and the Multiple Turing Machine is one of them.

In terms of physical world, the principle of multiple knowledge demonstrates a surprising similarity to the multiple-worlds theory (Deutsch 1998) or the multiverse theory (Ellis 2011). In both theories, there is a huge number of universes like ours in the superuniverse. The controversial theory of multiuniverse is based on physical observations that our universe is expanding ever faster while there is no enough matter or energy of any kind to support this. However, if multiple universes coexist, that would explain the gravity causing the ever faster expanding.

Whatever the case, the Turing machine very well corresponds to digital computers while there is no existing hypercomputer. It should be noted that quantum computers are just as powerful as Turing machines, even they compute based not on 0/1, but on a quantum superposition of the two.

As it turns out, the Turing machine and the halting machine are as fundamental concepts and principles as the other principles humans use, e.g. Einsteins', and have not changed during time.

Figure 4: The disputed multiverse theory there are many universes that pop from nowhere.

2.3. Turing test, birth of AI

In 1950 Turing published a paper describing the Turing test and a debate about artificial intelligence, then named »machine intelligence«. It was only in 1956 that McCarthy coined the »artificial intelligence« term and the field started growing enthusiastically.

Regarding the Turing test (Turing 1950), the best known and discussed test of all times, the issue is in comparing behaviors of two computing mechanisms (originally one human and one computer) and identifying the computing type of each of them. There are tens of different versions of the Turing test, e.g. a Total Turing Test (Harnad 1991) including physical tasks, and a Trully Total Turing test (Schweiser 1998), examining populations of test subjects.

In terms of latest definitions (Gams lecture 2011), intelligent systems and intelligence are defined with the ability to learn. All machine learning systems are therefore intelligent and practically every living being including bacteria and plants. But the Turing test deals with human-level intelligence which includes testing at that level.

In practical terms, the computers have improved their performance by a factor of 100.000 in the last 20 years, yet human interrogators decipher computers from humans in as many questions as before two decades. The reason is that current computers lack any human-level understanding. By verifying understanding of any sentence, all computer programs display tabula-rasa performance. This is the empirical argument of weak AI, claiming that computers need major improvements in order to approach human-level intelligence and computing (Gams 2001).

3 ALAN TURING AND DONALD MICHIE

Donald Michie and Alan Turing were together with other researchers decoding the Enigma, the German encrypting machine (Wikipedia). By use of electronic machines, the

counter-surveillance department was able to decode messages to German submarines. It is claimed that this was the most relevant civil discovery during the second world war and that several 100.000 lives were saved due to this. Due to being a secret, not much was known about this issue until decades later the data went public.

Alan Turing died committing a suicide with a poisoned apple, in an analogy to the Cinderella story. His death and previous sexual behavior led to Turing's legal prosecution, in today's view a major injustice to a loyal and honorable citizen that was undone only in 2009.

Unlike Alan Turing, Donald Michie (Srinivasan 2009) had a successful and long-term career in artificial intelligence. He was also the first one to establish an AI department in any institution in the world. Donald Michie was recipient of several established prices, including the Feigenbaum's medal and IJCAI's award in 2001. Donald Michie is especially important for Slovenian AI, and the Slovenian society SLAIS due to Michie's cooperation with Ivan Bratko. In last decades, Donald often spend one month of a year at the Jozef Stefan Institute in Ivan Bratko's room. The room is now named the Donald Michie room and is close to the central lecture hall at the institute.

4   DISCUSSION

If one types »Lady Gaga« into Google, 400 million hits are found, for »Mozart« around 132 million hits, for »Albert Einstein« 60 million and just 9 million for »Allan Turing«. In Amazon.com, around 10.000 book references are found for »Albert Einstein« in relation to 1.700 of »Alan Turing«. Yet, the Turing Award is generally regarded as the Nobel prize of computer science and Turing himself as »Einstein of computer science« by many scientists, including the author of this paper. Today, several publications refer to Turing as the father of computer science, artificial intelligence and mathematical biology.

It might not be reasonable to compare the fame of Lady Gaga to the fame of Turing, but why on Earth is Turing so unrecognized compared to the other world geniuses like Einstein or Mozart? But to what avail is that Turing is widely recognized in computer science and informatics, if an average European does know him while everybody knows Einstein or Mozart? The fact that Turing was neglected 60 years ago does not discard the fact that he is still neglected now as for example internet hits show.

It should not be only on us, computer science community, but on all scientists to revive the fallen acknowledgement of

an extraordinary scientist, demolished by intolerant bureaucrats. It should be only fair for the world to fully accept Turing as one of the most important people ever. If anybody for a second doubts about that, just look around and count the Turing machines embedded in the near-by machines. We should also remember Donald Michie as the Turing companion, in a list of computer geniuses that changed the world as hardly anybody else did.

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