Turing's Cathedral

The Origin of the Digital Universe

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The digital revolution meant that numbers apart from meaning something also were made to do something. Numbers occur in two different ways in a computer. One one hand they reside in memory physically represented[1] while their meaning resides in whoever interprets them, and ultimately there is a human interpreter at the end of a long chain of intermediate steps, in which the numbers may be interpreted by other computers, or being printed down on paper as text or on some screen, say as a sequence of pixels, which then becomes accessible to human cognition (a string of zeroes and one means little to a human observer). But numbers also do something, they are literally interpreted by the computer which translates them into different moves changing stationary numbers. Numbers become dynamic, represented not by fixed positions, but by changing positions, and this takes place in time and is is what is called a computation, and that is what computers do, namely compute. It is basically a deterministic process, in which the result is already implicit in the assumptions[2] and as such reminiscent of Laplace's demon. But what is a computation? Turing offered a definition in terms of the so called Turing machine a purely mental construct, and especially as it turned out to be equivalent to another rival interpretation, namely Church lamba-calculus, consensus is that it fully captures the intuitive notion of computation, neither more nor less. As a result one speaks about the Church-Turing thesis, the thesis being the claim above, that this is what computation is all about. In particular in Turing there is the notion of what a program is. Of course Turing was not the first one who introduced the notion of a program, in retrospect one can discern the principles, especially in mathematics, where the notion of an algorithm is a very old one. Also in Leibniz one can find many precursors to modern digitalization, and the daughter of Byron, Ada Lovelace is nowadays hailed as the first programmer as a result of her collaboration with Babbage. It is all about mechanization, and one of the first truly mechanized machines were the looms, which could be primitively programmed using punched cards, a tradition that survived into the 70's. The looms, unlike the calculating machines, were not designed to calculate, but ended up doing so, not with numbers literally interpreted, but with numbers nevertheless; thus the origin of the computer and programming may rather be sought among such inventions, because computers are not confined

[1] Stationary numbers are represented by positions, i.e. by space. The idea of taking advantage of relative positions, of course harks back to the invention of the positional system, which in its turn was inspired by the pre-computers such as abacuses.

[2] One may of course include in the input truly random processes, such as radioactive decay, making the outcome truly unpredictable, of course a computer can generate random processes, but this is more a matter of simulation and not the real thing. A program is by definition deterministic.

to deal with numbers as such, but to make numbers represent much more than numbers. To mechanize thoughts mean to decompose them into the smallest possible constituents, and it is in this regard that Turing's presentation is the simplest and most lucid[3]. Thus the origin of the title of the book. The modern computer which launched the digital age is simply an effort to make flesh out of the spirit of Turing's idea. To do so turned out to be quite intricate, but most important and surprisingly it was possible. It would not have been possible a hundred years ago, it was only the advance of physics and modern technology which supplied the means. The mystery lies in how to avoid hardware failure, which does not occur in a purely cerebral setting, as one simply prohibits it. There is after all a difference between the Platonic realm and the imperfections of the sub-lunar world. The miracle is that in spite of inevitable hardware failure the whole project can nevertheless be practically executed.

This is a story of how the first computer on Turing's principle was actually developed at the Institute of Advanced Study. There is a certain irony in this fact as the Institute was founded on the principle of pure and disinterested research un-sullied by practical applications and commercial projects. In fact there was opposition against it, as well as a rather snobby rejection of all the engineering riff-raff for whom office space and accommodation had to be provided. And the computer itself a huge machine in a basement[4], it must have been something of an abomination. The whole project would not have been possible without the passion and prestige of John von Neumann, who hence becomes the major protagonist of the story, not to say its hero. The book itself is an ambitious project, and like all biographies, it feels its needs to display almost everything that the persistent efforts of the biographer has unearthed, thus we are treated to all kinds of aspects, trivial as well as momentous, of the computer project. On one hand it is good that as much as possible is documented, trying to stave the tide of inevitable erosion and subsequent obliteration, that makes the past dimmer and prey to final oblivion, on the other hand too much detail may make any account tedious, The intention is laudable though, in its effort to create the time and the feeling of it, and the author being the son of Freeman Dyson, grew up at the Institute and must have imbibed its special atmosphere with his mother's milk, and thus be particularly well-positioned for the task, Thus apart from a through chronological documentation there are extensive biographical sketches of all the players, of whom there are so many, that the author, for which he should be commended, has felt it incumbent to include a long list of, which one as a reader constantly feels the need to consult. This makes out the bulk of the book and is as such fascinating. Even more fascinating are some scattered reflections of what computers really mean, what it is all about, issues which seem to be overwhelmed by contemporary discussions, in which computers seem to spell the source both of all human benefits as well as all its dooms, One is in particular thinking of so called artificial intelligence, which some people fear will run

[3] Definitely simpler than Church's calculus, of which even most mathematicians have a very hazy notion of.

[4] because this was the first generation of computers, with vacuum tubes and punched cards, then the transistor would be introduced, and later on the chip and the micro chip, which has made possible the remarkable reduction in physical size and expansion of storage and computational speed, known as Moore's law

out of control, and instead of being the master of computers we are in the end doomed to become their disposable slaves,

One may think of the computer project as a continuation of the Manhattan project, but with other means. There was one direct connection namely the development of hydrogen bombs which required extensive simulations and hence computations. Von Neumann had no moral qualms about such work, unlike the director of the Institute, the ill-fated Robert Oppenheimer. Another inspiration as a valuable application was weather forecasts. Von Neumann believed, naively or at least hastily in retrospect, that long range predictions would be possible, and where there was extreme sensitivity to initial data, there would be an opportunity, with a minimum of energy, to make drastic and directed impacts on weather, in short to improve it. Biological evolution was another avenue to be explored, and was in fact, in some ways similar in principle to weather forecasts but far more complicated, because as weather was concerned one could restrict oneself to a few well-known physical laws, and no such basis can be found for biological evolution. Both those two later aspects are touched upon at some length, while little is said about nuclear explosions, a topic which although ominous and of concern to most readers, few of them are familiar with the devils of the details necessary to make such accounts gripping (one suspects this is true of the author as well). Once again when it comes to computer applications Turing can be invoked, as he as a pioneer, was concerned with the great potential of computers, not just as work-horses for technical computation. Chess programs, embryology, and of course ultimately artificial intelligence gripped him, but this brave new world lay beyond the tenure of the Institute Machine, which after the untimely death of von Neumann, lost the spirit that had empowered it and was left in permanent decline, the supporting staff dismantled and dispersing, only the chief engineer who had been given tenure, remained, but unhappily and unproductively so. And the whole brief saga ended. The machine having been long since overtaken by rival teams, and now hopelessly obsolete, yet as it turned out, its influence on architecture is very much still in effect, this being the privilege of pioneers, setting the stage which will survive long after its constructors have passed away.

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