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Lady Lovelace's Objection: The Turing-Hartree Disputes over the Meaning of Digital Computers, 1946-1951

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Abstract—Can machines think? Or can they do "whatever we know how to order" them to perform? Should machines be liberated from slavery and given "fair play" to "compete with men in all purely intellectual fields"? Or should this be associated with a fashion that decries "human reason" and a path that "leads straight to Nazism"? In the postwar years, these questions were debated by Alan Turing and Douglas Hartree, who differed in their interpretations of the digital computer as a new piece of science and technology. Hartree emphasized its unprecedented calculation speed and envisioned applications in physics, logistics, energy, and warfare. Turing, who envisioned applications in biology and cognition, emphasized its potential to outperform humans intellectually, including capabilities considered distinctly human, which Hartree downplayed by mobilizing the notes of Ada Lovelace. This paper examines the Turing-Hartree disputes and draws a parallel between their positions and their perspectives on postwar Britain.

The debate was sparked by the English press in early November 1946 in the wake of a speech given by British statesman Louis Mountbatten (1900-1979) to the British Institution of Radio Engineers in London on October 31, 1946 [27].[1] It was an exciting time in Britain, if not for the mass of the people kept in austerity, controls, and rationing from the end of the war, certainly for the elite in power in the political, military, and scientific institutions. Talk of the emerging technologies of World War II could capture the public imagination, projecting futures in which postwar Britain would be a great power.

Mountbatten announced that the stage was set "for the most Wellsian development of all: the Electronic Brain." The media would pick up on the term, with a headline in *The Times* the next day.[2] The statesman went on to say, "It is now considered possible to evolve an electronic brain which will perform functions analogous to those at present undertaken by the semi-automatic portion of the human brain." He continued:

> That is to say, it will receive information about the situation of the machinery under its control, and will provide an intelligent—I repeat, intelligent—link between that information and the action necessary to keep the machinery in general conformity with the overall directions given to it by man. In providing this intelligent link between this information and the action necessary to control the machinery, the electronic brain will enormously extend the scope of the human brain, not only in essence but also in distance. [27, pp. 223-224]

Such an "intelligent" behavior would be possible by means of "radio valves" that "activat[e] each other in the way that brain cells do" (*ibid.*). The analogy of valves to brain cells and the earlier reference to the possibility of *evolving* an electronic brain suggest a particular view of early computing in the mid-1940s, the source of which will be suggested shortly.

To balance his "Wellsian" claims, Mountbatten referred to the existing Electronic Numeral Integrator and Computer (ENIAC), announced in February at the Moore School of Engineering in the United States [21]. And he acknowledged Vannevar Bush, possibly the main responsible for the decision to build the atomic

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[1] Identification of this event is due to Andrew Hodges [18, p. 347].

[2] "An Electronic Brain: Solving Abstruse Problems; Valves with a Memory." *The Times*. London, November 1, 1946.

bomb [7]. The prospects of the electronic brain in the Cold War were marked. "A machine of this kind," he added, "will receive information supplied to it by the various information systems; it will sort out this information, acting in accordance with overall directions given to it by human beings; even at a distance it will obey its orders."[3] But other, perhaps more playful, prospects were also hinted at when he added that some such machines "are now being designed to exercise those hitherto human prerogatives of choice and judgment." One of them "could even be made to play a rather mediocre game of chess!"

Although Mountbatten cited the ENIAC, his perspective on the future of computing did not come from ENIAC's inventors John Mauchly and J. Presper Eckert Jr.. Instead, Mountbatten relied on information obtained from the NPL, as reported in a letter to *The Times* by the director of the National Physical Laboratory (NPL), Charles Darwin.[4] Mountbatten combined information from Alan Turing (1912-1954) and Douglas Hartree (1897-1958).[5]

However, this article will show that Turing and Hartree disputed the meaning of digital computers as a new piece of science and technology, starting right after Mountbatten's discourse. Set in the heart of postwar England, their disputes can be seen as an excellent source of conceptual clarity for current debates about AI and its future. This moves away from priority disputes in the history of computing raised in the secondary literature and pursues a scientific controversy between primary subjects *within* science and technology as a method of historiography [29].

STATESMAN BRIEFED AT THE NPL

In October 1945, Turing had been hired by the NPL to lead the design of the British computing machine, which was named the Automatic Computing Engine (ACE). In February 1946, Turing submitted a design proposal to the NPL Executive Committee, including some of his earliest postwar projections about the future of computing and the possibility of teaching machines to play chess. "Can the machine play chess?," he asked and went on:

> It could be fairly easily be made to play a rather bad game. It would be bad because chess requires intelligence ... There are indications however that it is possible to make the machine to display intelligence at the risk of its making occasional serious mistakes. By following up this aspect the machine could probably be made to play very good chess.[6]

Considering Turing's report together with Darwin's letter to *The Times* suggests that the source of Mountbatten's projection of a chess-playing machine must have been Turing.

Hartree was regarded in Britain and the US as a leading expert on computing machines, particularly because of his experience with the ENIAC, which he was keen to report to *Nature* [11]. Hartree would soon become a member of the NPL Executive Committee. Turing had been recruited to the Mathematics Division by the Superintendent J. R. Womersley, a co-author with Hartree of a 1937 paper on a numerical method for solving partial differential equations [4].

The NPL Executive Committee would meet on March 19, 1946, and Turing was invited to present his report orally.[7] Before introducing Turing, Womersley reviewed the three "large calculating devices constructed in the U.S.A. during the war," and emphasized their high production costs. "It was interesting to note," Womersley continued, "that Dr. Turing's machine, when fully completed, would have a potential output of work greater than the three of them put together." This was possible, he considered, "because of the greater elaboration of the logical controls proposed by Dr. Turing." The edge of the British computer design, Womersley suggested, lay in "the fact that in Dr. Turing we had an expert in the field of mathematical logic."

Hartree's enthusiasm about the promised efficiency of Turing's proposed design appears in the minutes:

> Professor Hartree pointed out that the serial operation of the machine makes it very economical in its use of radio valves. It requires only 2000 valves as against 18000 in the ENIAC, and gives a "memory" capacity of 6000 numbers compared with the 20 numbers of the ENIAC. This greater capacity (and the higher speed) are attained at no greater cost than the ENIAC."[8]

[3] The *Western Daily Press* headlined "New Robot Brain Machines: It Will Obey Orders," p. 4.

[4] "He [Mountbatten] had been fully informed by us of our project of the automatic computing engine, but at our request he did not mention it explicitly because it had not yet been made public." *Times*, "The 'Electronic Brain,'" November 13, 1946, p. 7.

[5] For biographical portraits, see [28], [18], [4], [5].

[6] Archives Centre, King's College, Cambridge. AMT/C/32, "Proposed Electronic Calculator."

[7] Minutes of the Executive Committee of the NPL for 19 March 1946, NPL library.

[8] *ibid.*

This can explain Mountbatten's specific observation that ENIAC used "18,000 valves" and consumed "as much power as 100 electric radiators" [27].

Mountbatten had captured the public imagination with the image of an electronic brain. But in Hartree's view, he went too far in his claims.

THE TURING-HARTREE DISPUTES, 1946-1951

Hartree, who had recently moved from Manchester to Cambridge to take up his Plummer Chair of Mathematical Physics at the Cavendish Laboratory, sent a letter to *The Times* criticizing the newspaper's headline.[9] Without mentioning Ada Lovelace,[10] he wrote:

> These machines can only do precisely what they are instructed to do by the operators who set them up. It is true that they can be set up in such a way as to exercise a certain amount of judgment. But it must be clearly understood the situation in which judgment has to be exercised, the criteria to be applied, the way the results of applying these criteria are to be assessed, and the decisions as to the action to be taken on these results, must all be fully thought out and anticipated in setting up the machine." As I wrote in the article in *Nature* ... "use of the machine is no substitute for the thought of organizing the computations, only for the labour in carrying them out."

Hartree had made almost the same point in his *Nature* article published on October 12, 1946 [11, p. 505]. But he continued the letter, now criticizing the use of the term "electronic brain:"

> It seems to me that the distinction is important, and that the term 'electronic brain' obscures it, and is misleading in that it ascribes to the machine capabilities that it does not possess; and this is why I hope use of this term will be avoided in the future.

Hartree's sober recommendation also appears in his inaugural lecture at Cambridge [13]: "This point seems ... to be missed entirely by those who speak of a machine of this kind as an 'electronic brain'" (p. 21).[11]

Hartree may not have realized a social implication of his restriction of the new machines to "the labour in carrying out" the computations. A large workforce of human computers, mostly women, who had been essential to the wartime operations conducted at Bletchley Park, but not the mathematicians who organized the computations, would soon be replaced by the new machines in Britain.[12] Turing, for his part, would not let human displacement go unnoticed, as we shall see.

On the same day that Hartree's letter appeared in *The Times*, he was interviewed alongside Turing,[13] a proponent of the computer-brain analogy who would even refer to the "electronic brain" himself in a technical report to the NPL less than two years later [42, p. 420]. The difference in Turing's and Hartree's views of the meaning and significance of the new machines was marked. While Hartree envisioned practical applications of scientific computing, Turing envisioned the potential impact of computing on our view of nature and our place in it. The reporter noted: "Dr Turing, who conceived the idea of [ACE], said that he foresaw the time, possibly in 30 years, when it would be as easy to ask the machine a question as to ask a man." Contrary to Turing's views, Hartree rejected "any notion that [ACE] could ever be a complete substitute for the human brain." He linked the idea of machine intelligence to authoritarian regimes, adding, "The fashion which has sprung up in the last 20 years to decry human reason is a path which leads straight to Nazism." Turing, who had recruited himself to fight Nazi Germany in World War II, did not seem intimidated by Hartree's play of the Nazi card in another interview he gave the next day: "Dr Turing said that was looking far into the future ... The point was then put to him that chess and similar activities required judgment as well as memory, and Dr Turing agreed that that was a matter for the philosopher rather than the scientist. "But," he added, "that is a question we may be able to settle experimentally in about 100 years time."[14]

[9] *Times*, "The 'Electronic Brain': A Misleading Term; No Substitute for Thought," November 7, 1946.

[10] Augusta Ada King, Countess of Lovelace (1815-1852), hereafter referred to as Ada or Lady Lovelace. It is remarkable how this fascinating figure in the history of computing [10] would become the unexpected protagonist in their disputes, and later be regarded as the author of "the first algorithm intended for a computing machine" [26, p. 29].

[11] According to the *Cambridge University Reporter*, October 30, 1946, p. 231, the lecture was scheduled to place on November 13, 1946, at 4.45pm at the Cavendish Laboratory.

[12] The gender aspect of this issue has been documented by Mar Hicks [17]. Hartree's lack of sensitivity to the displacement of humans by machines was probably *not* a gender issue. "During his entire life," Fischer notes, "Hartree seemed to be comfortable working with women on an equal basis" [5, p. 19].

[13] *The Daily Telegraph*, "'ACE' will speed jet flying", November 8, 1946.

[14] *Surrey Comet*, November 9, 1946. Reproduced by Andrew Hodges [18, p. 349].

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Why did Turing tend to look further than Hartree? It is worth noting that their disputes continued through the late 1940s into the early 1950s, appearing indirectly every year from 1946 to 1950 [12], [41], [42], [14], [15], [16], and directly in 1950 and 1951 [40], [19].

These events will be covered chronologically as we proceed. We can now examine Hartree's argument more closely.

THE MASTER PROGRAMMER

In 1946 through 1949, Hartree centered his arguments on the ENIAC and its "master programmer" unit as the paradigm of an electronic computer. He referred to the master programmer as "a most important unit of the ENIAC from the point of view of the organisation of a computation" [11, p. 504]. Hartree described it as a number of electronic switches, which were capable of controlling the computing sequence so that it could take different branches according to the partial results computed. He was referring to the concept of conditional branching as part of "sequence programming."[15]

Especially in 1946, Hartree was fascinated by this form of automation technology, which could be applied, most notably for Hartree, to "the step-by-step procedure numerical integration of a system of simultaneous ordinary differential equations" [11, p. 504].

The master programmer, wrote Hartree, "introduces a very considerable degree of flexibility into the ENIAC, and makes possible its automatic application to problems involving a considerable degree of discrimination and judgment." "But," he would emphasize again and again since his *Nature* paper, all the situations and decisions "must be fully anticipated in the setting up of the machine" [11, p. 505].

In his inaugural lecture [13, p. 23], Hartree illustrated his point (Hartree's emphasis):

> [I]f the quotient of two numbers is required in the course of the work, and the divisor happens to be zero, a human computer might do various things, but would certainly *not* go on for ever trying to divide by zero, which is what the machine *would* do unless it had been specifically instructed not to.

Hartree framed his view of computing in numerical analysis. In this field, problems are well-defined and the distinction between analysis, which requires thought, and routine operations is relatively clear.

[15]For a contextualized description of the ENIAC master programmer unit, see [9].

It is worth noting at this point that the Turing-Hartree disputes arose not from scientific differences, but from philosophical, social, and cultural ones. In a lesser-known seminar on minds and machines on October 27, 1949 [45], at the Philosophy Department of Manchester University, Turing was confronted with a discussion of rule-following behavior, and with the claim that "the vital difference seems to be that a machine is not conscious." (Compare Hartree on machine-based division.) To this, Turing is reported to have replied:

> [A] machine may act according to two different sets of rules, e.g. if I do an addition sum on the blackboard in two different ways:
>
> 1. by a conscious working towards the solution
>
> 2. by a routine, habitual method
>
> then the operation involves in the first place the particular *method* by which I perform the addition – this is conscious: and in the second place the neural mechanism is in operation unconsciously all the while. These are two different things, and should be kept separate. [45, no emphasis added]

Turing makes a distinction similar to Hartree's. But he considered the "conscious working towards the solution" to be within the scope of machines, while Hartree reserved it for humans. By "machine" they both meant digital computers, as opposed to analog machines, which Hartree distinguished as "instruments" [11, p. 500], and living things, which Turing excluded from his discussion [40, pp. 435-436]. Referring to the same object, they defended different interpretations of it. Turing, looking forward, sought the logical capabilities of digital computers under a machine model and architecture different from the "universal machine" he had presented in 1936.[16] Hartree, focusing on the known capabilities of existing machines such as the ENIAC, tried to leave the door open. But he had no time for the future.[17]

There is another historical actor whose perspective

[16]"If the untrained infant's mind is to become an intelligent one, it must acquire both discipline and initiative. So far we have been considering only discipline. To convert a brain or machine into a universal machine is the extremest form of discipline ... But discipline is certainly not enough in itself to produce intelligence" [42, pp. 429-430].

[17]"Even if some of the organization of the calculations is done by the machine, as is possible in future developments, the operator will still have to think out the sequence of operating instructions which will enable the machine to do this organization ... This is for the future" [13, p. 21].

will open an important window into the social and cultural context of the Turing-Hartree disputes.

WHY NOT "ROBOT," OR "ARTIFICE"?

The Cold War backdrop is particularly evident in the contributions of Wolfe Mays (1912-2005), a philosopher who met Turing at the 1949 Manchester seminar mentioned above. He also became a critic of Turing, and to this task he found support in Hartree:

> As Hartree warns us, the "specialized use of words already current may lead to misunderstanding, particularly when words habitually used in connection with living organisms, and especially with human activities, such as 'memory,' 'choice,' 'judgment' are applied to mechanisms." [22, p. 153]

Like Hartree, Mays wanted to deter Turing's suggested association of the words "machine" and "thinking." He offered "robot" and "artifice" instead:

> [I]t may be necessary to introduce a new label to indicate a device which simulates overt human activities without at the same time duplicating our internal behaviour. The word is ready to hand and was coined by Karel Capek, we call them 'robots' ... In this connection it might be a good thing to drop the word 'machine,' with its emotional overtones of clanging metal, and use some such neutral word as 'artifice.' [22, p. 150]

Three years later, in the United States, John McCarthy et al. did just that [24]. Seeking philanthropic and Cold War patronage, they dropped "machine" for "artifice" in coining the term "artificial intelligence."Mays ended his paper connecting Turing's "machine analogy" with an Orwellian dictatorship and the "Master Programmer:"

> It is not altogether too fanciful to suppose that the machine analogy, with its emphasis on overt behaviour and abnegation of private experience may, when the doctrines of 'Cybernetics' finally percolate down to the lower grades of the Civil Service, lead us to be regarded, more than ever before, as if we were mechanical objects. It is not such a far cry from Aristotle's view that slaves were just human tools, to some future benevolent dictatorship of the Orwell 1984 type, where men may be seen as little else but inefficient digital computors and God [Big Brother] as the Master Programmer.[18] [22, p. 162]

It is unlikely that the source from which Mays borrowed the specialized term "master programmer" was not Hartree, since Mays directly cites *Calculating Instruments and Machines* where the term appears.

Mays and Hartree may not have noticed that the use of the word "master" to name the control unit of the ENIAC may have struck Turing in his turn.

SHOULD MACHINES BE TREATED AS SLAVES?

A few months after Hartree's inaugural lecture and BBC broadcast, Turing would make the master-slave dichotomy a dominant theme at the end of his lecture on the ACE to the London Mathematical Society on February 20, 1947:

> It has been said that computing machines can only carry out the processes that they are instructed to do. This is certainly true in the sense that if they do something other than what they were instructed then they have just made some mistake. [41, pp. 392-393]

Having admitted that the dictum is true in so far as misbehavior is considered an error, he continued:

> It is also true that the intention in constructing these machines in the first instance is to treat them as slaves, giving them only jobs which have been thought out in detail, jobs such that the user of the machine fully understands what in principle is going on all the time. (*ibid.*)

Turing resumed observing: "Up till the present machines have only been used in this way" and asked: "But is it necessary that they should always be used in such a manner?" [41, p. 393].

Turing's plea to free "machines" from slavery actually appeared in his lecture after questioning the ethics of their embodied masters, the programmers:

> Roughly speaking those who work in connection with the ACE will be divided into its masters and its servants. Its masters will plan out instruction tables for it, thinking up deeper and deeper ways of using it. Its servants will feed it with cards as it calls for them ... As time goes on the calculator itself will take over the functions both of masters and of servants. [41, p. 392]

[18] In a postscript Mays wrote fifty years later [23], perhaps relying inadvertently on an earlier version of his original manuscript, "Big Brother" appears substituting for "God" as the "Master Programmer."

Turing resumed his talk and casually revealed that the master-servant division, in this context, also corresponded to a gender division: “One might for instance provide curve followers to enable data to be taken direct from curves instead of having girls read off values and punch them on cards” (*ibid.*). Here, Turing’s references to “man” as a masculine generic were in fact materially marked by the male gender. The “girls,” the “servants,” would become a class below the machines.[19] What about the “masters”?

Turing’s focus in his masters-servants remark is on the division of labor and the power imbalance between intellectual and non-intellectual (so-called “mechanical”) work, which was evident at Bletchley Park during the war.[20] He went on to emphasize what he saw as the “real danger:”

> The masters are liable to get replaced because as soon as any technique becomes at all stereotyped it becomes possible to devise a system of instruction tables which will enable the electronic computer to do it for itself. It may happen however that the masters will refuse to do this. They may be unwilling to let their jobs be stolen from them in this way. In that case they would surround the whole of their work with mystery and make excuses, couched in well chosen gibberish, whenever any dangerous suggestions were made. I think that a reaction of this kind is a very real danger. [41, p. 392]

Here Turing gave a first answer to Hartree: even if automation were driven by humans themselves, the progress in the range of automated tasks would eventually lead to a conflict of interest. How would the “masters” react? That they would perceive the machines as a threat to their dominant position, that was the real danger. If machines were going to displace the lower classes of workers, he implied, they should also be allowed to displace the higher classes as well.

Not only Hartree, but also Darwin had spared the jobs of those whom Turing called “masters” in his letter to *The Times* in November 1946.[21] Turing was saying to the London Mathematical Society — and it is not unlikely that Darwin and Hartree were in the audience — that they, the mathematicians, might try to suppress intelligent machines to protect their jobs. Hodges interpreted Turing’s remarks as a direct, unwise, response to Darwin’s letter: “To describe such careful and responsible statements [Darwin’s] as ‘gibberish’ was not the most tactful policy” (p. 357). Hodges notes Turing’s lack of diplomatic skills, but this should not overshadow Turing’s deliberate challenge to Darwin, Hartree, the NPL senior management, and the mathematicians in the audience. In 1948, Turing would generalize his argument to “intellectual people” and their “unwillingness to admit the possibility that mankind can have any rivals in intellectual power” [42]. In 1951, he addressed “intellectuals” who would be “afraid of being out of a job” [44].

After Turing’s ethical argument, which was probably unexpected and unsettling to his interlocutors at the time, there came his theoretical argument about machine intelligence as a sustained response to Hartree’s critique. Intelligent behavior, for Turing, is a result of learning, a capability he had no problem attributing to digital computers:

> One can imagine that after the machine had been operating for some time, the instructions would have altered out of all recognition ... Possibly it might still be getting results of the type desired when the machine was first set up ... In such a case one would have to admit that the progress of the machine had not been foreseen when its original instructions were put in ... When this happens I feel that one is obliged to regard the machine as showing intelligence. As soon as one can provide a reasonably large memory capacity it should be possible to begin to experiment on these lines ... What we want is a machine that can learn from experience. The possibility of letting the machine alter its own instructions provides the mechanism for this. [41, p. 393]

Note that the machine’s storage capacity is the physical property that makes his concept of logical univer-

[19]For the sex division of labor in the postwar British computer industry, see Hicks [17].

[20]Hodges put it this way [18]: “To the dismay of conservative forces, British society had undergone a second and more thorough shaking up, this time with knowledge and ideas communicated to those excluded from participation in peace — ordinary men, the young, and even women. Bletchley Park had seen this happen as much as anywhere else. It had not been all a story of “men of the Professor type;” there had been boys of eighteen, “female mathematicians,” and Post Office engineers who had risen from the bottom of the ladder, all playing crucial parts” (p. 311).

[21]“In popular language the word ‘brain’ is associated with the higher realms of the intellect, but in fact a very great part of the brain is an unconscious automatic machine producing precise and sometimes very complicated reactions to stimuli. This is the only part of the brain we may aspire to imitate. The new machines will in no way replace thought, but rather they will increase the need for it ...” *Times*, “The ‘Electronic Brain,’ ” November 13, 1946, p. 7.

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sality practically relevant.[22]

In the wake of Mountbatten's speech, Turing had replied to a letter written to the NPL by the psychiatrist Ross Ashby. This 1946 source makes it clear that, for him, just as the brain changes its neural connections in response to stimuli, a computer program should be able to change its instruction tables.[23]

LADY LOVELACE'S OBJECTION

Hartree would become the author of what Turing would call in his *Mind* 1950 paper:

> (6) Lady Lovelace's Objection. Our most detailed information of Babbage's Analytical Engine comes from a memoir by Lady Lovelace. In it she states, "The Analytical Engine has no pretensions to *originate* anything. It can do *whatever we know how to order it* to perform" (her italics). [40, p. 450]

Turing continued to reproduce Hartree's exact words:

> This statement is quoted by Hartree [15, p. 70] who adds: "This does not imply that it may not be possible to construct electronic equipment which will "think for itself," or in which, in biological terms, one could set up a conditioned reflex, which would serve as a basis for "learning." Whether this is possible in principle or not is a stimulating and exciting question, suggested by some of these recent developments. But it did not seem that the machines constructed or projected at the time had this property.

Turing found the door Hartree had left open refreshing. He added, "I am in thorough agreement with Hartree over this. It will be noticed that he does not assert that the machines in question had not got the property, but rather that the evidence available to Lady Lovelace did not encourage her to believe that they had it."

Turing's philosophical response was to shift the question and return the burden of proof:

> A variant of Lady Lovelace's objection states that a machine can "never do anything really new." This may be parried for a moment with the saw, "There is nothing new under the sun." Who can be certain that "original work" that he has done was not simply the growth of the seed planted in him by teaching, or the effect of following well-known general principles.

Turing wrote his *Mind* paper near the Christmas Eve of 1949, less than six months after the publication of Hartree's lectures at the University of Illinois [15], from which Turing quoted. At Illinois, apparently for the first time, Hartree noted Ada Lovelace and linked his views to her.[24] He presented a brief reading of her substantial notes on a memoir of Charles Babbage's Analytical Engine written by the military engineer Luigi Menabrea [20].[25]

Lovelace was the daughter of the Romantic poet Lord Byron (1788-1824).[26] In early 1812, when the House of Lords voted on a bill calling for the death penalty for frame-breakers, the Luddites, her father delivered an ironic, impassioned speech in their defense. He described the protesting workers as "liable to conviction on the clearest evidence of the capital crime of poverty ... nefariously guilty of lawfully begetting children whom, thanks to the times, they are unable to maintain."[27] Lovelace's mother, born Annabelle (1792-

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[22] In 1948, Turing would write: "In particular with a B-type unorganised machine with sufficient units one can find initial conditions which will make it into a universal machine with a given storage capacity" [42, p. 422]. The work of Hava Siegelmann and Eduardo Sontag [34] continues this tradition.

[23] Letter from Alan Turing to W Ross Ashby, circa November 19, 1946. British Library, Add MS 89153/26.

[24] After Hartree, the British industrialist Vivian Bowden (1910-1989) would dedicate his 1953 edited collection, *Faster than Thought* [2], to Ada Lovelace, reprint her translation of Menabrea and her notes as an appendix, and give a brief biographical account of her, writing (p. 19): "Very little seems to be generally known about Ada Augusta, Countess of Lovelace." James Sumner notes that Bowden attributed his learning of Lovelace and Babbage to Hartree in correspondence with Brian Randell, March 1972, University of Manchester Archives, BVB/1/82, folder 2 [36]. Hartree first mentions Babbage, but not yet Lovelace, in his BBC broadcast of December 1946 [12].

[25] The Lovelace quote is taken out of context from her Note G [20, p. 722] by Hartree, and then read more carefully by Turing, who is rightly concerned about Hartree's anachronism, but also does not seem to have looked further into Lovelace's original material. Lovelace is in a direct dialogue with Menabrea's statements, namely (p. 675): "It [human intervention] is necessarily thus; for the machine is not a thinking being, but simply an automaton which acts according to the laws imposed upon it;" and (p. 689) "Thus, although it is not itself the being that reflects, it may yet be considered as the being which executes the conceptions of intelligence*." (Lovelace adds a footnote to the word 'intelligence,' referring directly to her Note G.)

[26] For a biographical portrait of Ada Lovelace, see [33]. For context and discussion of her notes, and analysis of her vision and remarks on computing, see [6], [10], [38], [39].

[27] Speech of Lord Byron upon the "Frame Work" Bill, delivered in the House of Lords, 27 February 1812. British Library, Egerton MS 2030: 19th century. Byron wrote a poem, "Ode to the Framers of the Frame Bill," first published by the *Morning Chronicle*, Monday, March 2, 1812.

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1860) and married to become Lady Byron, was by all accounts an analytical woman who did not accept her husband's unreasonable behavior at home, ranging from poor financial management and drinking to dark moods and anger. They separated when Lovelace was only five weeks old. Lady Byron had sole custody of Ada ever since. In the words of Betty Toole [39], "Ada's heritage" consisted of "two diametrically opposed points of view: her mother, the archetype of the new industrial age who could use analysis, facts, and objectivity to gain her clearly defined goals, and her father, the romantic poet, who took life as it came without predetermined goals and used imagination to view the world through a subjective lens."

When Lovelace was seven years old, her father asked her mother if the girl was "imaginative" [33, Ch. 10]. But Annabelle made every effort to ensure that Lovelace did not to grow up with her father's behavior and dark moods. She was schooled in science and mathematics and discouraged from literature. In this Annabelle was not entirely successful. According to Toole, "Ada verbalized this struggle when she wrote in an undated fragment to Lady Byron: "You will not concede me philosophical poetry. Invert the order! Will you give me poetical philosophy, poetical science?" Eventually, Lovelace sought to be recruited by Charles Babbage (1791-1891) for his Analytical Engine project, writing to him on February 16, 1840:

> You know I am by nature a bit of a philosopher, & a very great speculator, so that I look on through a very immeasurable vista, and though I see nothing but vague & cloudy uncertainty in the foreground of our being, yet I fancy I discern a very bright light a good way further on, and this makes me care much less about the cloudiness & indistinctness which is near. Am I too imaginative for you? I think not."[28]

Like Turing, Lovelace showed an inclination towards imagining the future. But the extent to which Lovelace was allowed to be imaginative was a recurring question. And the question of how open to interpretation Lovelace's words are would become the crux of the dispute between Hartree and Turing, being a major theme in their May 1951 radio broadcasts.[29]

[28] Lovelace to Babbage, February 16, 1840. British Library, Correspondence of Charles Babbage, Add MS 37192.

[29] Jones covers this BBC broadcast series in breadth [19], including the format and context of the Third Programme drawing from Asa Briggs as his main source [3, pp. 50-84].

THE 1951 BBC BROADCASTS

The BBC Third Programme was a national radio service launched in September 1946. It was intended to complement the Home Service and the Light Programme, to be of "a high cultural level," devoted to the arts, serious discussion and experiment, and to "provide an intelligent alternative at peak hours" [3, p. 66]. Its general audience in the late 1940s was claimed to be between 1.5 and 2.5 million, but a typical audience for a broadcast would be around 90,000 [19]. This audience was nonetheless influential, consisting mainly of academics, artists, and the intelligentsia, but also of working-class listeners — the distribution surveyed in 1949 was 28/37/35 percent of upper-class, middle-class, and working-class listeners, respectively.[30]

At the climax of his BBC lecture on May 5, 1951 [19], Hartree admitted that digital computers could play games like chess, but again he mobilized Lovelace's dictum to downplay it:

> [...And this] would come very near what, in ordinary speech, we would call thinking—an aspect of those machines on which I understand Dr. Turing will be speaking. But remember, that the sequence of operations for such a process still has to be programmed, and Lady Lovelace's words still apply—"the machine can *only* do what we know how to order it to perform." (emphasis added)

Perhaps inadvertently, Hartree added the word "only" to Lovelace's words, and this would not pass unnoticed by Turing in his own BBC lecture, delivered ten days later on May 15, 1951.

In his own broadcast, Turing quoted Lovelace's precise words and noted:

> The sense of the rest of the passage is such that one is tempted to say that the machine can *only* do what we know how to order it to perform. But I think this would not be true. Certainly the machine can only do what we do order it to perform, anything else would be a mechanical fault. But there is no need to suppose that, when we give it its orders we know what we are doing, what the consequences of these orders are going to be. One does not need to be able to understand how these orders lead to the machine's subsequent behaviour, any more than one needs to understand the mechanism of germination

[30] The same distribution for the Light Programme was 3/18/79, and for the Home Service was 7/24/69 [3, p. 83].

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> when one puts a seed in the ground. [43, p. 485, Turing's emphasis]

Early on in his talk, he said that he would articulate the view, which he held himself, "that it is not altogether unreasonable to describe digital computers as brains." "A different point of view," he added, "has already been put by Professor Hartree."[31] Turing then insisted on a more open interpretation of Lovelace's words [43]: "I agree with Lady Lovelace's dictum as far as it goes, but I believe that its validity depends on considering how digital computers *are* used rather than how they *could* be used" (p. 482, his emphasis). He compared the use of digital computers proposed by "the majority of scientists," whose "outlook was well summed up by Lady Lovelace," to the planning of a military operation:

> For any one calculation the whole procedure that the machine is to go through is planned out in advance by a mathematician. The less doubt there is about what is going to happen the better the mathematician is pleased. It is like planning a military operation. Under these circumstances it is fair to say that the machine doesn't originate anything.[32]

"In fact," he added, "I believe that they [digital computers] could be used in such a manner that they could appropriately be described as brains."

At the climax of his broadcast, Turing delivered these words, which must have sounded unsettling:

> I have tried to explain what are the main rational arguments for and against the theory that machines could be made to think, but something should also be said about the irrational arguments. Many people are extremely opposed to the idea of machine that thinks, but I do not believe that it is for any of the reasons that I have given, or any other rational reason, but simply because they do not like the idea. One can see many features which make it unpleasant. If a machine can think, it might think more intelligently than we do, and then where should we be? [43, pp. 485-486]

This is reminiscent of the objection to the possibility of machine intelligence he named "Heads in the Sand" before [40, p. 444]. But here, speaking to the nation on the radio, Turing used irony and, as it seems, wanted to warn the general public about a scenario that he foresaw:

> Even if we could keep the machines in a subservient position, for instance by turning off the power at strategic moments, we should, as a species, feel greatly humbled. A similar danger and humiliation threatens us from the possibility that we might be superseded by the pig or the rat. This is a theoretical possibility which is hardly controversial, but we have lived with pigs and rats for so long without their intelligence much increasing, that we no longer trouble ourselves about this possibility. We feel that if it is to happen at all it will not be for several million years to come. But this new danger is much closer. If it comes at all it will almost certainly be within the next millennium. It is remote but not astronomically remote, and is certainly something which can give us anxiety. [43, pp. 485-486]

Certainly Turing looked far beyond Hartree. We can now ask why.

HARTREE'S POSTWAR BRITAIN

It is possible to trace Hartree's life-long interest in automating calculations to his early experiences in anti-aircraft gunnery, especially during World War I [1], [4]. He became an expert on the calculation of trajectories, which involved much numerical work with pencil and paper. In addition to the control of ballistic trajectories, Hartree also developed an early interest in the control of railroad traffic, which, as Agar notes, would lead him to appreciate signaling methods [1]:

> From boyhood Hartree had a strong interest in railways and their signalling methods, and in later life this proved useful to the railway companies in relation to their complicated traffic problems. He served on a committee of the British Transport Commission and showed how to use the high-speed computing machines to solve traffic problems which had previously taken months of calculation.

This helps explain Hartree's enthusiasm for ENIAC's electronic control unit, the master programmer.

Hartree would continue to develop his work on the calculation of trajectories "all through his life, and he came to be regarded as a world leader in computation, called in as consultant in many countries" [1]. Perhaps his most famous scientific contribution is his insight into

[31] In Turing's original typescript, he wrote, "The opposite point of view has already been put by Professor Hartree." On second thought he changed it to "A different point of view ..." Modern Achive Centre, King's College, Cambridge, AMT/B/5.

[32] Compare Turing's 1948 remark (note 16) about the need to introduce "initiative" into a machine, as opposed to following orders, in order for it to exhibit intelligence.

how to solve the Schrödinger equation for a multielectron atom using a self-consistent field approximation scheme [25]. This scheme, which was generalized by the Russian physicist Vladimir Fock (1898-1974), is called the Hartree-Fock method and is widely used to describe electrons in atoms, molecules, and solids.

Hartree's interests centered on military, scientific, and logistical applications of computing — and, in his spare time, on classical music, even participating in the university orchestras in Manchester and Cambridge [4], [5]. He was enthusiastic about spreading the use of electronic computers, as he envisioned them, to British institutions and society at large. That Mountbatten, a top statesman, was helping to spread what Hartree considered to be phoney ideas about the new machines must have been distressing to him. Fischer offers an anecdote: "In the past, Hartree generally despised those who wrote letters to the *Times* so his family teased him unmercifully for writing one himself" [5, p. 154].

In postwar England, Hartree was settled, but Turing was not.

TURING'S UTOPIA

The word "utopia" comes from the Greek "topos," meaning "place" or "where," and "u" from the prefix "ou," meaning "no" or "not," and has come to refer to a non-existent place. For this reason, "to call something 'utopian' has, from very early on, been a way of dismissing it as unrealistic" [32, pp. 14-15]. But Thomas More (1478-1535), a statesman and disputed historical figure who coined the term in the 1510s,[33] also used the prefix "eu" to write "eutopia," meaning a happy land, and the word "utopia" itself came to refer to an idealized, non-existent good place.[34]

A utopian frame of mind arises from the experience of bad times, which produces visions of a utopian future in which the ills of society have been eliminated, replaced, or transcended. What evils would have led Turing to adopt a utopian frame of mind and project his vision so far beyond his peers? In his communications and writings, Turing provided some clues to it. With his peculiar touch of irony [8], he addressed the chauvinisms of religion, ethnicity, nationality, and race.[35] These added to his strong critique of anthropocentrism, or species chauvinism, inviting humanity to look at itself. Beyond habits and customs, his irony addressed social and institutional structures, especially the division of labor and the role of intellectuals.

The intelligent machines that Turing envisioned differ in important ways from today's artificial intelligence. Educated by individuals rather than by large corporations or nation-states, his ever-learning child machines would grow their intelligence out of their own experiences rather than have it synthesized [8]. Turing rarely used the word "artificial," and when he did, it was to express distaste. In 1951, he clarified his naturalistic philosophy by hoping that "no great efforts" would be put "into making machines with the most distinctively human, but non-intellectual characteristics, such as the shape of the human body." This would be "quite futile" and "their results would have something like the unpleasant quality of artificial flowers" [43, p. 486]. His intelligent machines would have limited agency in the world, functioning more as intellectual and educational devices to deconstruct human prejudices.

In addition to learning how to write sonnets and discussing their interpretation [40, p. 446], the intelligent machines that Turing envisioned could possibly acquire the capabilities of (p. 447): "be kind, resourceful, beautiful, friendly, have initiative, have a sense of humour, tell right from wrong, make mistakes, fall in love, enjoy strawberries and cream, make some one fall in love with it, learn from experience, use words properly, be the subject of its own thought, have as much diversity of behaviour as a man, do something really new." For Turing, these were "possibilities of the near future, rather than Utopian dreams" (p. 449). And yet he conceived them from a utopian frame of mind, aspiring to a different society.

History can provide perspective and offer alternatives to the present. Turing's utopianism can be seen as

[33] *Utopia*, 1516. British Library, C.27.b.30.

[34] More noted the disruptive "enclosures" under the Tudors, which were rapidly changing land tenure and use in England and Wales [37]. These changes and the extinction of rights of common were impoverishing ordinary people, depriving them of their capacity to live, and forcing them into the new institution of wage labor. Despite More's critical perception of the enclosures, he imagined — some claim he satirized — yet another patriarchal state based on colonial conquest and slavery. For an exegesis of More's five-hundred-year-old work, see [30]. The modern genre of utopianism has long since outgrown More's work [31].

[35] In 1950, he wrote [40]: "The arbitrary character of the orthodox view becomes clearer if we consider how it might appear to a member of some other religious community" (p. 443); "The works and customs of mankind do not seem to be very suitable material to which to apply scientific induction ... Otherwise we may (as most English children do) decide that everybody speaks English, and that it is silly to learn French" (p. 448); "the difficulty of the same kind of friendliness occurring between man and machine as between white man and white man, or between black man and black man" (*ibid.*).

an alternative to today's techno-utopias, not least because he owned no means of production, turned away from power, and was a relatively socially vulnerable individual. One might say that his utopia remains just out of reach. But the overtones here may depend on how tempted one is to declare the end of history.

CONCLUSION

This article has pursued a scientific controversy in the history of computing as a method of historiography [29]. Turing and Hartree played opposing roles in an important dispute, 1946-1951, at a crucial juncture in history. Their debate provides an excellent source for the questions outlined in the abstract of this paper, including what machines can and cannot do, and the prospects of intelligent machines in society. Their questions are as relevant today as they were then.

A remarkable anecdote from the 1990s illustrates the continuing tension over the issues debated by Turing and Hartree. In an interview, Marvin Minsky (1927-2016) reported [35]: "It is worth remembering that Nathaniel Rochester at IBM referred to the IBM 701 computer as 'smart,' and it nearly got him fired. The highest officials at IBM ... wanted to reassure their potential customers that IBM products would only do what they were programmed to do" (p. 28).[36] The problem reappears today under names such as "explainable" and, more broadly, "responsible" AI.

Turing thought far ahead of his time and was not well understood by his contemporaries. Wolfe Mays was keen on his Orwellian foreshadowing of the institutional use of digital computers by nation-states to control populations. But in teaching himself from Hartree's lectures, Mays seems to have reversed Turing's and Hartree's intended uses of the digital computer: he invoked the "Master Programmer" to criticize Turing instead of Hartree. Unlike Hartree's calculating, order-following machines, Turing's ever-learning machines would be human-like, allowed to develop a subjectivity and make mistakes.

Ada Lovelace was fought over by her analytic mother and romantic father, and it is remarkable that more than a hundred years later, she would become the unexpected protagonist of a new round of disputes. Neither Turing nor Hartree seems to have taken their reading of the little-known "Lady Lovelace" much further, although both warmly acknowledged her contribution to their debate. Of all the computer pioneers of the twentieth century, Hartree seems to have been the one who noticed Lovelace and her remarkable notes, until then overshadowed by Babbage. However, the one who combined sharp analytical power with an imaginative, if not romantic, view of machines in the tradition of Ada Lovelace, a view that suggested uses of computers away from hubris, power, and control, is certainly Alan Turing. After Lovelace's notes were published, she wrote (her emphasis):

> Lord L [Lovelace], sometimes says "what a *General* you would make!" Fancy me in times of social & political trouble, (had *worldly* power, rule, & ambition been my line, which it could never be) ...
>
> *My* kingdom however is not to be a *temporal* one, thank Heaven! ...[37]

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[36] Compared to Lovelace's words, it is worth noting the addition of "only," just as Turing noted that Hartree did.

[37] Lovelace to Babbage; July 5, 1843. British Library, Correspondence of Charles Babbage, Add MS 37192.

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