DAVID LINK

There Must Be an Angel
On the Beginnings of the Arithmetics of Rays

From August 1953 to May 1954 strange love-letters appeared on the notice board of Manchester University's Computer Department:[1]

> "DARLING SWEETHEART
> YOU ARE MY AVID FELLOW FEELING. MY AFFECTION CURIOUSLY CLINGS TO YOUR PASSIONATE WISH. MY LIKING YEARNS FOR YOUR HEART. YOU ARE MY WISTFUL SYMPATHY: MY TENDER LIKING.
> YOURS BEAUTIFULLY
> M.U.C."[2]

The acronym "M.U.C." stood for "Manchester University Computer", the earliest electronic, programmable, and universal calculating machine; the fully functional prototype was completed in June 1948.[3] One of the very first software developers, Christopher Strachey (1916–1975), had used the built-in random generator of the Ferranti Mark I, the first industrially produced computer of this kind, to generate texts that are intended to express and arouse emotions. The

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1 T. William Olle, personal communication, 21 February 2006: "I do remember a copy of the Strachey love-letter being put on the notice board and that must have been after August 1953 and probably prior to May 1954 (the date of Alan Turing's death)."

2 Christopher Strachey, The "thinking" machine. *Encounter. Literature, Arts, Politics* 13 (1954): 25–31, p. 26.

3 Frederic C. Williams and Tom Kilburn, Electronic digital computers. *Nature* 162 (1948): 487. By "computing" and "calculating" I mean here and in the following in general the processing of data. Various machines are claimed to be the "first" computer, but all others lack one of the properties mentioned. The "ABC", developed by John V. Atanasoff and Clifford Berry 1937–1941 in the U.S.A., was a binary digital "equation solver" and remained unfinished due to World War II. intervening. From 1938, in Berlin Konrad Zuse constructed a series of electro-mechanical binary digital equation solvers, culminating in 1941 in the functioning model "Z3". Both projects included a certain internal memory for numbers but not for instructions. The same applies to "COLOSSUS", completed in the U.K. in December 1943, and the North American "ENIAC" of November 1945. On both machines the instructions were plugged via cables. See Simon Lavington, *Early British Computers* (Manchester, 1980), p. 4ff. Lavington offers an easy and readable account of the early history of computers in Great Britain.

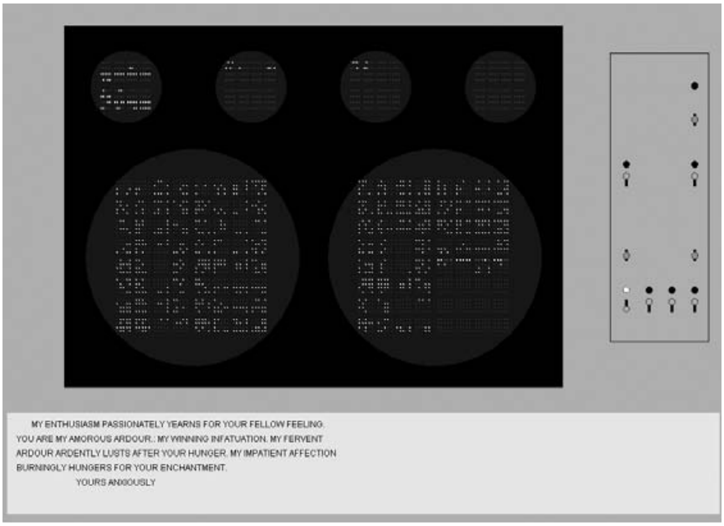

Figure 1: The user interface of the Ferranti Mark I emulator with the Love-letters algorithm loaded.

British physicist performed this experiment a full thirteen years before the appearance of Joseph Weizenbaum's *ELIZA*, which is commonly—and mistakenly—held to be the earliest example of computer-generated texts.[4]

Using numerous resources I found on the internet, I constructed an emulator of the Ferranti Mark I, and ran Strachey's original programme on it, which is preserved in his papers held by the Bodleian Library in Oxford.[5] Thus the

4 Joseph Weizenbaum, ELIZA. A computer program for the study of natural language communication between man and machine. *Communications of the ACM* 9 (1966): 36–45.

5 The emulator can be found on the author's website at http://alpha60.de/research/muc/. I particularly used documents that Brian Napper has made available on the website http://www.computer50.org/, Alan Turing's *Programmers' Handbook for the Manchester Electronic Computer Mark II* (Manchester, 1951), available online in two versions, http://www.turingarchive.org/browse.php/B/32, http://www.alanturing.net/turing_archive/, transcript at http://www.computer50.org/kgill/mark1/progman. html, and Dietrich G. Prinz, *Introduction to Programming on the Manchester Electronic Digital Computer* (Manchester, 1952), online: http://www.alanturing.net/turing_archive/archive/m/m11/M11-001.html. The manuscripts of the love-letter programme are held in the Special Collections and Western Manuscripts section of the Bodleian Library, Oxford University, CSAC 71.1.80/C.34 and C.35. My warmest thanks go to Brian Napper, Christopher P. Burton, Martin Campbell-Kelly, Simon Lavington, and T. William Olle for their exceptionally generous support, tips, and suggestions.

following analysis of how the hard- and software functions is not only based on theoretical consideration of the subject matter, but equally on transforming "thought into being and put its trust in the absolute difference" during the long and arduous reconstruction of the details, and to "stretching it [the mind] on the rack in order to perfect it as a machine".[6]

Programme of a Love-letter

After studying mathematics and physics at King's College, Cambridge, during the war Christopher Strachey worked for Standard Telephones and Cables Ltd. in London on electron tubes for centimetric radar. In this work he made use of the differential analyser invented by Vannevar Bush, which awakened his interest in computers.[7] After the capitulation of Germany, Strachey became a teacher. In January 1951 a friend introduced him to Mike Woodger of the National Physical Laboratory (NPL). The lab had successfully built a reduced version of Turing's Automatic Computing Engine (ACE) the concept of which dated from 1945: the Pilot ACE. In May 1950 the first computations were performed on this machine. After the meeting with Woodger, in his spare time Strachey developed a programme for the game of draughts, which he finished in February 1951. The game completed exhausted the Pilot ACE's memory. The draughts programme ran for the first time on 30 July 1951 at NPL, and developed into an early attempt at getting a computer to write its own programme, so-called auto-coding.

When Strachey heard about the Manchester Mark I, which had a much bigger memory, he asked his former fellow-student Alan Turing for the manual, transcribed his programme into the operation codes of that machine by around October 1951, and was given permission to run it on the computer.

"Strachey sent his programme for punching beforehand. The programme was about 20 pages long (over a thousand instructions), and the naiveté of a first-time user attempting a programme of such length caused not a little amusement among the programmers in the laboratory. Anyway, the day came and Strachey loaded his programme into the Mark I. After a couple of errors were fixed, the programme ran straight through and finished by playing 'God Save the King' on

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6 Georg W.F. Hegel, *The Phenomenology of Spirit* [1807], trans. A.V. Miller (Oxford, 1977), p. 400 (the "beautiful soul"); idem, *Science of Logic* [1812], trans. A.V. Miller (London, 1969), p. 217.

7 On Strachey's biography see Martin Campbell-Kelly, Christopher Strachey, 1916–1975. A biographical note. *Annals of the History of Computing* 7 (1985): 19–42.

the ‘hooter’ (loudspeaker). On that day Strachey acquired a formidable reputation as a programmer that he never lost.”[8]

Because of this achievement, the National Research and Development Corporation (NRDC) offered Strachey the post of technical officer the following month. Figure 2 shows the general structure of the Love-letters software, in Strachey’s handwriting, that he developed in June 1952 along with two other small projects soon after joining NRDC.[9]

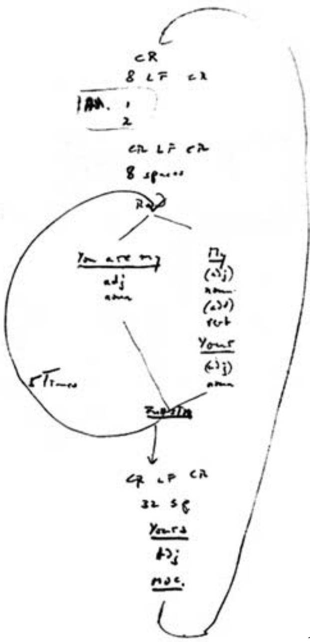

Figure 2: Schematic of the Love-letters programme.[10]

8 M. Campbell-Kelly, Programming the Mark I. Early programming activity at the University of Manchester. *Annals of the History of Computing* 2 (1980): 130–168, p. 133. The precise article describes the machine in technical detail. Strachey’s accomplishment is all the more admirable since Turing’s manual teems with mistakes and inaccuracies. It forced the reader to do some “de-bugging” immediately and painfully to complete a learning process of the foreign language. Cf. Frank Sumner, Memories of the Manchester Mark 1. *Computer Resurrection. The Bulletin of the Computer Conservation Society* 10 (1994), 9–13, p. 9: “So all the programmes written in Mark 1 code had slight errors in them, and by the time you had worked out what the code should have been you had become quite a competent programmer.”

9 The other two projects, commissioned by NRDC, concerned the computation of a surge shaft and the Ising model of ferromagnetism; cf. National Cataloguing Unit for the Archives of Contemporary Scientists (NCUACS), *Catalogue of the Papers and Correspondence of Christopher Strachey (1916–1975). CSAC No. 71/1/80* (Bath, 1980). http://www.a2a.org.uk/search/extended.asp, Catalogue ref. NCUACS 71.1.80.

Apart from position commands like carriage return ("CR"), line forward ("LF"), and spaces ("spaces" or "sp"), the algorithm prints two salutations ("Add." = address). Then it enters a loop, which is carried out "5 times" and, depending on a random variable ("Rand"), follows one of two alternative paths. One generates a sentence following the syntactic skeleton "You are my—Adjective (adj)—Substantive (noun)"; the other path gives "My—[Adjective]—Substantive—[Adverb (adv)]—Verb (verb)—Your—[Adjective]—Substantive" (the static words are underlined, the optional words are in square brackets). The first sentence of the example given at the beginning of this chapter follows the first scheme, and the second sentence follows the other. Each phrase ends with a "Full stop". After the programme leaves the loop, it closes with the ending "Yours—Adverb (in the schematic this is given erroneously as 'Adj')—MUC."

The University of Manchester's Computer

From a technical perspective, the Universal Machine that Alan Turing (1912–1954) designed theoretically in 1936 can be reduced to a problem of memory.[11] It had to be capable of writing, reading, storing, and deleting any data. To this purpose, the engineer Frederic Williams (1911–1977) had modified cathode ray tubes common in both warfare and commercial applications (CRTs—like the ones still used in television sets) for the Manchester Mark I in such a way that electronics repeatedly read and refreshed the 1280 picture dots.[12] The screen was divided into two columns each with 32 lines of 20 bits. Eight of these monitors were employed to load and run programme pages (data and operations). The size of the main working memory was around 1.25 kilobytes. On two monitors connected in parallel the user could see directly the content of the various tubes.[13]

10 All images of the original programme are from the Special Collections and Western Manuscripts section of the Bodleian Library, Oxford University, CSAC 71.1.80/C.34 and C.35 by kind permission.

11 A.M. Turing, On computable numbers, with an application to the Entscheidungsproblem. *Proceedings of the London Mathematical Society (2)* 42 (1936–37): 230–265. Cf. F.C. Williams and T. Kilburn, A storage system for use with binary-digital computing machines. *Proceedings of the Institution of Electrical Engineers, Part II* 96 (1949): 183–202, p. 183: "The problem of electronic digital computing from the engineering standpoint, lies primarily in the construction of suitable electronic devices having the same number of states as the number of possible values of a digit."

12 Williams also began his career in radar research, which I discuss below.

13 These are the two larger circular disks in Figure 3. Cf. Campbell-Kelly, Mark I, p. 154: "The ease with which monitor tubes could be used with CRT storage was a very attractive feature of this tech-

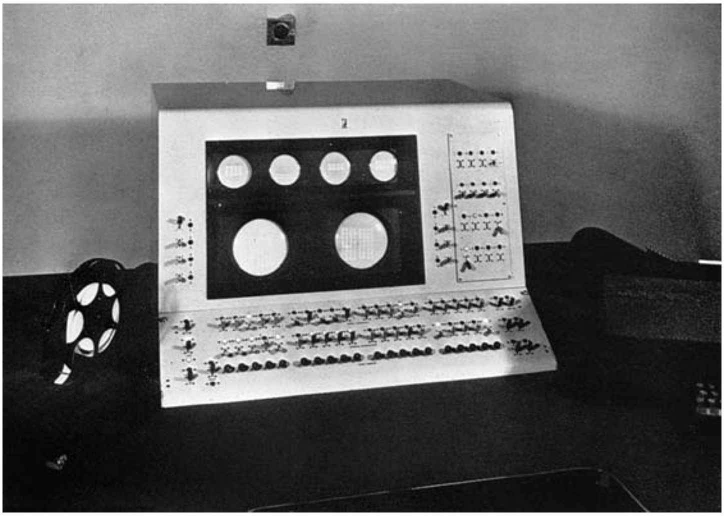

Figure 3: The console of the Ferranti Mark I. Top: The monitor tubes B, C, A, and D. Bottom: Two pages of the main memory.[14]

A magnetic drum was available for long-term storage of data. The programmer could load the data from there onto one of the monitors or save data from the monitor in the drum.[15] The actual processing was done on four smaller tubes, whose content was also visible, and which were labelled with the first four letters of the alphabet. A, the accumulator, contained the results of the arithmetical and logical operations and also temporarily stored data for the transmission from one line of the page to another. In the C tube (C for control) was the

nology; there is no equivalent for today's memories. By sitting at the console, the programmer could observe the progress of the programme on the monitor tubes in a process known as 'peeping'. Peeping was very much the modus operandi at Manchester."

14 Bertram V. Bowden, ed., *Faster than Thought. A Symposium on Digital Computing Machines* (London, 1953), p. 127.

15 The magnetic drum was located in a room above the actual computer workshop, which led to introduction of the terms "down transfer" and "up transfer" for these two operations that live on in the modern variants "upload" and "download". Cf. Prinz, *Introduction*, p. 23; F.C. Williams, Early computers at Manchester University. *The Radio and Electric Engineer* 45 (1975): 327–331, p. 328: "The two-level storage I have referred to was indeed on two levels. The electronic store was in the magnetism room and the magnetic store in the room above. Transfers between the stores were achieved by setting switches, then running to the bottom of the stairs and shouting 'We are ready to receive track 17 on tube 1'."

current instruction and its address. The most momentous invention for the later development of computers lay in the auxiliary store B, which was given this letter because A and C were already in use. The content of B could be added to the current command and thus could modify it before it was carried out. Today, this is termed "index addressing" and it allows a single instruction to be applied to a list of any length.[16] Finally, D contained the multiplier in appropriate calculations. The computer not only displayed the data, operations, and addresses on the CRTs (this must be considered a side-effect of the chosen medium), it stored, read, wrote, and processed these in the electrical charges of the picture dots.[17]

Routines of Love

Strachey's programme filled four double monitor storage units. The word data needed for the letters was located on the last three pages, written backwards; the main algorithm was on the first page.[18]

In addition the software had two sub-routines: "PERM" and "ENGPRINT". "PERM" enabled generic library functions to be linked in and belonged as it were to the development environment, the Scheme A. It overwrote the main programme in memory with another, executed it, then restored the original state, and followed the instructions from the point at which it had left them. "ENGPRINT", the only sub-algorithm the programme used, printed the symbols at the address, which was set in Line 4 of Tube B; it printed them line by line and backwards until it encountered the meta-symbol """. To generate text from the words stored on pages 2–4, the variable only had to be assigned a value repeatedly and the print routine called up. The problem of generating text was reduced to the administration of addresses.

A "word" of Mark I.—the smallest unit of information used—was 20 bits long. On the recommendation of Geoff Tootill, and later Turing, outside the computer these were represented by four letters of the Baudot alphabet (common in telegraphy), each of which was 5 bits. The sequence of symbols is shown in the

16 Cf. Campbell-Kelly, Mark I, p. 135.

17 Semiologically, this positions the symbols, which the machine processes, before differentiation between letter and number. The symbols simply mark the pure difference. See David Link, while(true). On the fluidity of signs in Hegel, Gödel, and Turing, in: *Variantology 1. On Deep Time Relations of Arts, Sciences and Technologies*, eds. Siegfried Zielinski and Silvia Wagnermaier (Cologne, 2005), pp. 261–278.

18 See Figure 4. The first adjectives are: "anxious", "wistful", "curious", and "craving".

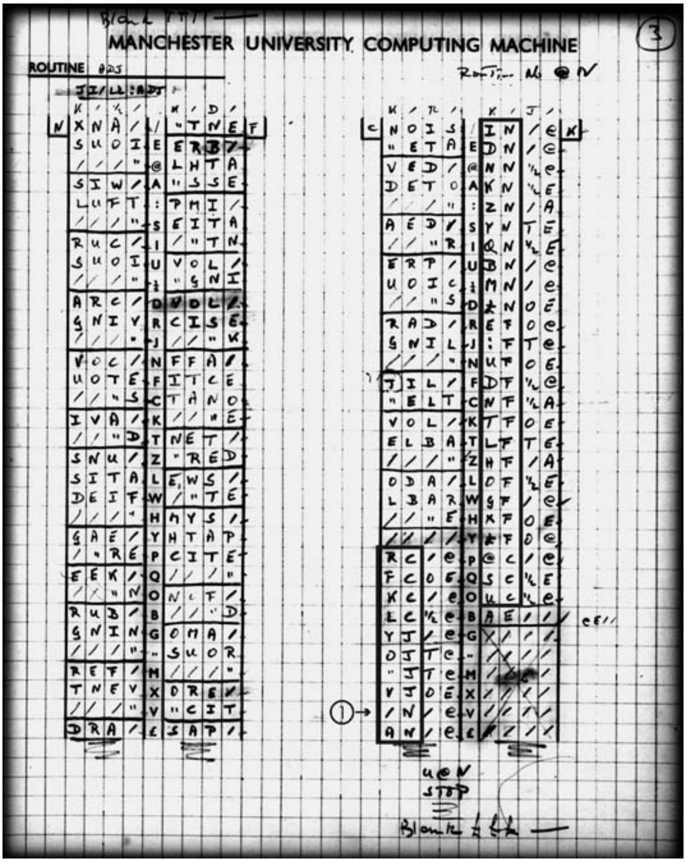

Figure 4: The list of adjectives in Love-letters, page 3 of the programme.

middle columns of Figure 4, where they number the lines of the programme: "/E@A:SIU..." . As one can see in the boxes that are appended at the top of both sides of the tables, these are Columns 13–16 (N, F, C, K), which constituted the fourth of the eight tubes. Simon Lavington comments aptly: "To Turing, who had spent countless hours at Bletchley Park battling with Geheimschreiber 5-bit ciphers during the war, the teleprinter code must have seemed very natural. To lesser mortals it was painful!"[19] To work with this representation was made even more difficult by the fact that the usual order of numbers was reversed. The

19 Lavington, *Early British Computers*, p. 42.

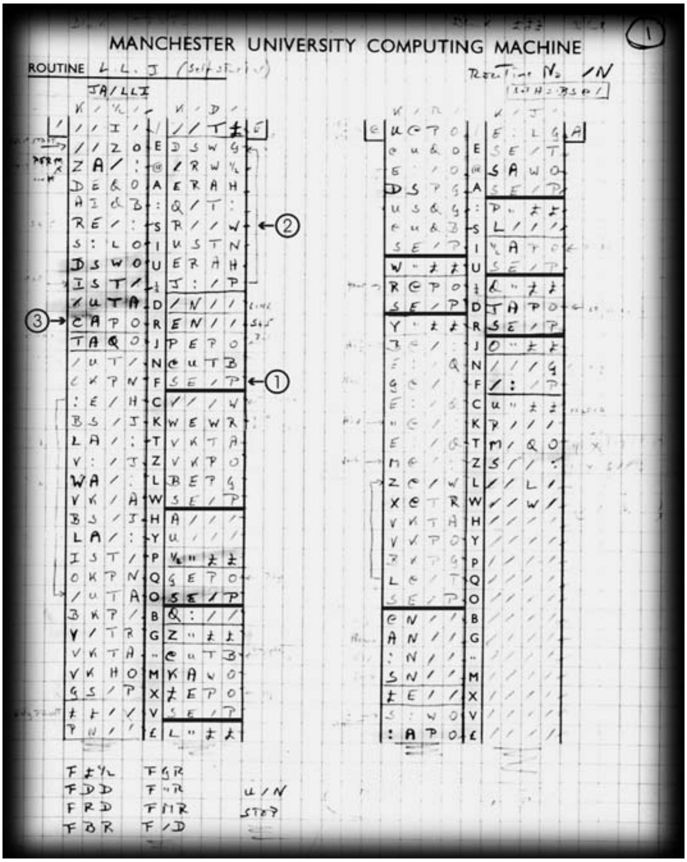

Figure 5: The first page of Strachey's algorithm.

so-called "highest significant bit" (the bit with the highest value) was not on the left but on the right; 1000 was thus represented as 0001. Campbell-Kelly explains: "The reason for this is that in a serial machine, the digits are produced least-significant first; Williams tubes and oscilloscopes conventionally sweep with time going from left to right, so it was natural to write binary numbers that way and this was common on early computers."[20] The addresses of the lines were also written backwards in this notation. The word "anxious" at the top left of Figure 4 is in position "/N", which together with the positions of all the other words on

20 Campbell-Kelly, Mark I, p. 136.

the page is found in the right-hand table, in the first two signs of the penultimate line of the left-hand column (1). “AN” beneath it references “wistful”, etc.

To understand the structure of a command of the Manchester computer, let us take as an example the sequence “SE/P”, which appears in Line “FE” of the main programme, amongst others (1 in Figure 5). In general, in the machine’s instruction set the last two symbols indicate the command that is to be performed, and the first two symbols indicate the address to which it refers. “/P” means an unconditional jump to the line that “SE” references. At position “SE” the algorithm finds the first two signs “R/” (2). Thus “SE/P” encodes the instruction to continue with execution in Column 1, Line 11 (3). Through this command that stands at the end of many of the sections that are separated by horizontal lines, the software always returns to its beginning in order to execute one of the routines for the definition of the address of the next word to be printed—dependent on Line 3 of Tube B, to write the address in Line 4, and to call up the output-programme.

Variable Scripts

Astonishingly, according to Joseph Weizenbaum, he knew nothing of Strachey’s experiments when he wrote *ELIZA*, although in this period computer departments in England and North America maintained lively communications and visited each other regularly.[21] This is even more odd considering that in 1962, Strachey corresponded with Weizenbaum, and at the time *ELIZA* was published, Strachey was Guest Lecturer at the Massachusetts Institute of Technology (MIT) for seven months. Strachey had also cleared up the organisational issues concerning his term at MIT with Weizenbaum. The British scientist continued to give summer lectures regularly at MIT until 1970.[22] I, too, knew nothing about Strachey’s programme when I wrote my Ph.D. dissertation on early algorithms for generating text.[23] In my endeavour to derive the more complex procedures from the simpler ones, at that time I selected an example dating from 1997, because I could not find a study object to illustrate the most basic form of meaning production, which logically preceded *ELIZA* and was chronologically

21 J. Weizenbaum, personal communication, 3 May 2006.

22 Cf. NCUACS, *Catalogue of Strachey Papers*, CSAC 71.1.80/A.66, CSAC 71.1.80/C.202–C.207.

23 D. Link, *Poesiemaschinen / Maschinenpoesie* (Ph.D. diss., Humboldt-University, Berlin, and Academy of Arts and the Media, Cologne, 2004). http://edoc.hu-berlin.de/docviews/abstract.php?lang=ger&id=25251, pp. 24ff. In German.

fitting.[24] Strachey's programme discussed here closes the gap in a satisfying way and in general falls into the category of variable scripts. A series of abstract signifiers references a list of equally possible, concrete instantiations, which are inserted for them at random and independent of each other. The fascinating thing about this was and is that seemingly endless variety can be generated from a relatively small group of words, as expressed in the title of one of the first literary experiments in this direction, Raymond Queneau's "Cent mille milliards de poèmes".[25] Strachey strengthened the impression of great diversity by not only varying the words used, but also including optional elements, which were sometimes omitted and thus modified the structure of the sentences. Additionally, two different syntactic structures alternated at random. When the construction "You are my—Adjective—Substantive" repeated, the programme shortened the second instance to ":my—Adjective—Substantive", thus cleverly avoiding repetition.[26] In total, Strachey's software could generate over 318 billion different love-letters.

Like *ELIZA*, *Love-letters* used personal pronouns to create a relationship between two communication partners. Both sentence constructions used relate "my" to "you", or "your", but not in the form of a dialogue where "you" would be transformed on the other side into "me" and vice versa, as is the case with *ELIZA*. Because *Love-letters* did not display the result but printed it because this was easier to realise technically, the addressee of the letters remains ambiguous. The computer is either writing to or for its user. Ultimately, the software bases on a reductionist position vis à vis love and its expression. Like the draughts game that Strachey had attempted to implement the previous year, love is regarded as a recombinatory procedure with recurring elements, which can be formalised, but which is still intelligent enough to raise considerable interest should it succeed.

The Quest for a Magic Writing-Pad

The condition of possibility of computers is on the one hand to reduce fundamental arithmetic operations to the simple transformation of primitive symbols according to rules, which themselves can be represented and treated as symbols. From 1906 onward, the Norwegian mathematician Axel Thue initiated work on

24 Nick Sullivan, *Romance Writer. Computer-Generated Romance Stories* [1997]. http://www.familygames.com/features/humor/romance.html.

25 Raymond Queneau, *Cent mille milliards de poèmes* (Paris, 1961).

26 Cf. the end of the example quoted at the beginning of this article.

this reduction; Kurt Gödel, and then Alan Turing, developed it together with all the paradoxes that resulted.[27] However, this kind of understanding of symbols has implicitly existed in cryptography since Girolamo Cardano (1550/1561) and Blaise de Vigenère (1586); today the term is "autokey". Like calculation with bits, secret ciphers transform a chain of source symbols (the plain text) using fixed rules (the key, often in the form of a tableau) into a different text (the cipher text). What is special about the autokey is the fact that the substitution routine depends directly on the message that is to be communicated. Thus already here data and operations converged in so far as both are symbols.[28]

On the other hand, and very practically, the symbols also had to be represented in their fluidity. This demanded a medium that was capable of both storing and selectively "forgetting". In 1925, when he was nearly seventy, Sigmund Freud wrote in his "Note Upon the Magic Writing-Pad":

"All the forms of auxiliary apparatus which we have invented for the improvement or intensification of our sensory functions are built on the same model as the sense organs themselves […]. Measured by this standard, devices to aid our memory seem particularly imperfect, since our mental apparatus accomplishes precisely what they cannot: it has an unlimited receptive capacity for new perceptions and nevertheless lays down permanent […] memory-traces of them."[29]

In a close parallel to Turing's experience of changing into a machine, Freud turns to the medium that he uses for writing notes: the sheet of paper. This material offers him the possibility to put down his thoughts, but not to delete or change the symbols, except if he uses an eraser. As with Turing, mistrust of the memory or forgetfulness makes it plausible to export the mental functions entirely.[30] Because Freud is unable to erase the symbols already written down, he is

27 Axel Thue, Über unendliche Zeichenreihen. *Kristiania Vidensk. Selsk. Skrifter. I. Mat. Nat. Kl.* 7 (1906): 1–22; Kurt Gödel, Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme, I. *Monatshefte für Mathematik und Physik* 38 (1931): 173–198; Turing, Computable numbers.

28 Cf. David Kahn, *The Codebreakers. The Story of Secret Writing* (New York, 1967), p. 143ff. Here I can only mention this connection in passing.

29 Sigmund Freud, A note upon the "Mystic Writing-Pad" [1925], in: *The Standard Edition of the Complete Psychological Works of Sigmund Freud*, ed. James Strachey (London, 1961), vol. 19, pp. 225–232, quotation p. 228. The editor and psychoanalyst James Strachey was Christopher Strachey's uncle.

30 Cf. Turing, Computable numbers, p. 253: "It is always possible for the [human] computer to break off from his work, to go away and forget all about it, and later to come back and go on with it." and Freud, Writing-pad, p. 227: "If I distrust my memory—neurotics, as we know, do so to a remarkable extent, but normal people have every reason for doing so as well—I am able to supplement and guarantee its working by making a note in writing."

obliged to continue recording his thoughts on a new page when the first is full. He can turn back through the notes, which are possibly interdependent, to re-read the contents. The process of writing, however, is step-wise and only moves forward, limited like a Markov chain.[31]

Freud discovers in this magical toy a procedure that records in a radically different way. A single area is filled with symbols and then erased, over and over again. "If we imagine one hand writing upon the surface of the Magic Writing-Pad while another periodically raises its covering-sheet from the wax slab, we shall have a concrete representation of the way in which I tried to picture the functioning of the perceptual apparatus of our mind."[32] In 1923, a certain Howard L. Fischer from the Brown and Bigelow Co., Minnesota, U.S.A., applied for a patent for this device, which was named the "Perpetual Memorandum Pad".[33] On the surface of the lower, wax-coated leaf, which the design inherits from Aristotle, the symbols overlap in natural stochastics to form traces.[34] In this device, the letter currently visible is only a condensed interim result of all the writing that has been done before. It loses its solidity. Future note-taking may strengthen other traces and the constant succession of setting down and erasing, by lifting up the top transparent leaf, may produce a different result. As at the beginning of Hegel's *Logic*, the alternation of "being" and "nothing" on the top page of the magic pad produces the possibility of "becoming" on the second underlying page: here the symbols transform.[35] Freud's interpretation, if not the invention of the magic pad, is clearly stamped with the concept of cinematography. Constancy, duration, arises through and is re-interpreted as constant repetition of the same, as repetition of identical acts of writing.

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31 Cf. Andrey A. Markov, Essai d'une recherche statistique sur le texte du roman "Eugène Oněgin", illustrant la liaison des épreuves en chaîne. *Bulletin de l'Académie Impériale des Sciences de St.-Pétersbourg (6)* 7 (1913): 153–162. In Russian. Translation into German in the Appendix of the author's Ph.D. dissertation (Link, *Poesiemaschinen*, 187–203); English translation forthcoming.

32 Freud, Writing-pad, p. 232, translation slightly altered. Freud is already thinking in terms of a periodic cycle.

33 Cf. the *DEPATIS* system of the German Patent Office (Deutschen Patent- und Markenamtes, DPMA), http://depatisnet.dpma.de/DepatisNet/depatisnet, patent no. US 1,543,430.

34 Cf. Aristotle, On the soul, in: *The Works of Aristotle. Vol. 3. Meteorologica*, *De mundo*, *De anima*, *Parva naturalia*, *De spiritu*, ed. William D. Ross and John A. Smith (Oxford, 1908–1952), Book 2, Chapter 12: "By a 'sense' is meant what has the power of receiving into itself the sensible forms of things without the matter. This must be conceived of as taking place in the way in which a piece of wax takes on the impress of a signet-ring without the iron or gold."

35 Cf. Link, while(true), p. 265f.

The "delay line", one of the first inventions for volatile storage of data, achieved this sameness by reflection.[36] A piezo-electric crystal transformed electric oscillations into ultrasound waves, which excited water or kerosene in a tube; in later versions of the apparatus mercury was used. The waves travelled through the tube, and were then taken up by another quartz crystal, which amplified the waves and fed them back into the front of the tube. The writing, the time-delayed reading, and the re-writing of what was read realised continuity. The fundamental cycle, or loop, implemented the duration of symbols under technically changed conditions.[37] The delay line was not invented after the Second World War by Presper Eckert in North America, as is often maintained, but already in 1938 by William S. Percival at Electric and Musical Industries Ltd., EMI for short, in Hayes, Middlesex, in England, in connection with work on reducing interference in the transmission of moving images. Headed by Isaac Shoenberg and Alan Blumlein, as of 1929 an extremely creative team of engineers formed at EMI. Their inventions included such fundamental advances as stereophony (1931) and electronic High Definition Television (from 1933).[38] The latter culminated in 1936 in the introduction of HDTV for the first BBC transmitting station at Alexandra Palace in London. Percival's system used an auxiliary channel, which only transmitted the interference noise encountered, with the purpose of interrupting the main signal when a particular threshold was crossed and replacing it with neutral data like a grey value. To gain time for processing and generating the control signal, it was necessary to delay the stream of images.[39]

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36 Before the invention of the delay line other elements also existed for temporarily preserving "states", such as electro-mechanical relays or flip-flop circuits from Braun tubes; however, these could not be used extensively due to small storage capacity, relative expense, and slow switching. Cf. Lavington, *Early British Computers*, p. 13ff.

37 Freud had already come across a medium that could be used as volatile storage in one of his earliest texts, the "Project for a scientific psychology" from 1895, where he wrote about the "striking contrast" of the properties of nervous tissue and "the behaviour of a material that permits the passage of a wave-movement and thereafter returns to its former condition". The only idea missing was the lossless and, therefore, infinite echo. Cf. Alexandre Métraux, Metamorphosen der Hirnwissenschaft. Warum Freuds "Entwurf einer Psychologie" aufgegeben wurde, in: *Ecce Cortex. Beiträge zur Geschichte des modernen Gehirns*, ed. Michael Hagner (Göttingen, 1999), pp. 75–109, p. 102.

38 For the early history of television, see Siegfried Zielinski, *Deep Time of the Media. Toward an Archaeology of Hearing and Seeing by Technical Means* (Cambridge, MA, 2006), p. 236f. Zielinski attributes the development of the technology to the St. Petersburg electrochemist and -physicist Boris L. Rosing; Shoenberg studied with Rosing before the 1918 Revolution.

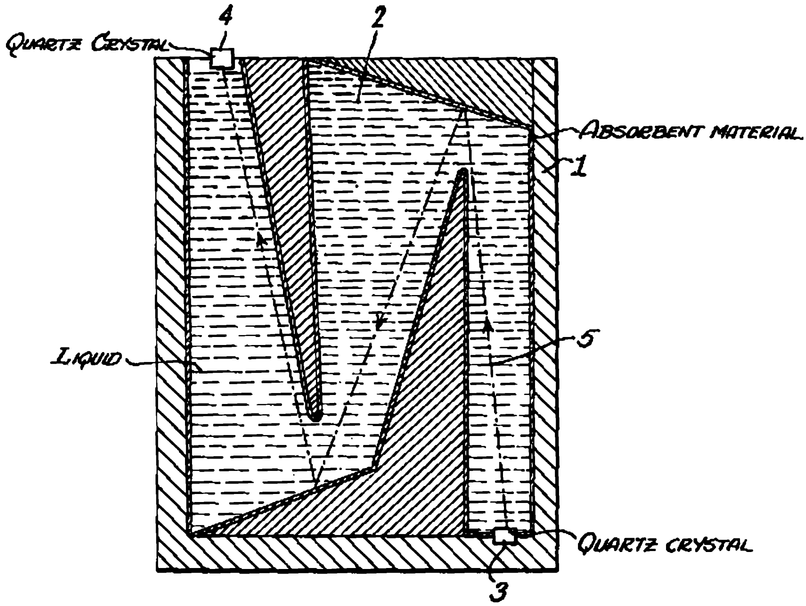

Figure 6: Diagram of the "Delay Device" in William Percival's patent.[40]

With live transmission of television to a vast number of receivers the recording and reproduction procedures, in which the "pencil of Nature" determined the representation, reached a limit.[41] Previously, media such as photography had claimed to deliver a faithful, true-to-life image of nature where no subjective will or style intervened. Now various kinds of interference that were equally natural threatened to disturb severely the distribution channels.[42] Whereas in the cinema it was possible to exert tight control over the distribution of information, TV technicians were confronted by a bewildering array of diverse scenarios for

39 Cf. *DEPATIS*, patent no. US 2,263,902 and US 468,994. Televisions still contain delay circuits today.

40 Cf. *DEPATIS*, US 2,263,902, p. 2: "The liquid container may be tubular in shape or narrow in one dimension and wide in another or wide in both dimensions."

41 Cf. Henry Fox Talbot, *The Pencil of Nature* (London, 1844).

42 Radio broadcasts publicly. Since no channel shields the transmission, anyone can read and write it, that is, tap it or disturb it. Interference and eavesdropping are two sides of the same coin as are the corresponding countermeasures, filtering and encryption.

transmitting and receiving images as well as various external influences on them.[43] Percival's idea represents a first, simple solution of the problem that Nature often writes itself a bit too much into any recording un-mediated by a subject. The filtering of the data contains an automatic, numerical comparative operation and produces a blind area in the stream of moving representations.

The delay line makes use of the fact that, in send/receive systems like telegraphy or telephony, information requires a certain time to get from the entrance to the exit and during this time it is stored in the cable. The carrier thereby transfers an arbitrary number of volatile, different symbols. As a hybrid and transition between communication medium and storage medium the device connected two points; not two humans communicating with each other, but the reading and writing heads of the same circuit. The transformation of the signal into ultrasonic waves made the time longer that the signal required to travel through the device. The idea of feeding it back into the system at the front probably originated in connection with experience of acoustic echoes in telegraph and telephone systems.[44]

In communication, delay is a most unwelcome phenomenon, but from the angle described above, it is volatile, short-term storage. Long-term memory, too, originated from a new interpretation of a technical disturbance—feedback. Extremely irritating when exchanging data through a channel that is supposed to be empty in order to send and receive information, it demonstrated the technical feasibility of storage in an ephemeral medium.

The tube containing liquid preserved a chain of pulses. Because the pulses travelled at the speed of sound, they were not only stored in space but in time, too. The distance from one crystal to the other and the time that the wave took to traverse this distance provided the basic beat. In addition a clock drove the line so that symbols could be positioned within the flow of time: "This clocking

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43 The openness of the system proved to be especially problematic because any device that contained coils, like an electric motor, emitted radio waves. Household machines such as electric shavers, vacuum cleaners, kitchen machines, etc., became potential sources of disturbance.

44 Alan Blumlein, the technical director of the EMI research group, began his career in 1924 as a telephone engineer at Bell Labs. There he developed a coiled cable that reduced mutual interference between channels (cross-talk) in long-distance telephone systems. In the early 1970s, the well-known telephone hacker John Draper, a.k.a. Captain Crunch, also sought the experience of continuity in volatile communication systems: "The hack, in this instance, refers to such technological stunts as having two phones on the table; talking into one, and hearing your voice in the other after a time-delay in which the original call has first been routed around the world." (Paul Taylor, *Hackers. Crime and the Digital Sublime* (London, 1999), p. 15. The acoustic coupling of the telephones' two receivers would have produced a storage medium.

is very important as it must keep the pulses in step as well as prevent degeneration of the pulses over a number of cycles."[45] It is not the pulses themselves that are reflected repeatedly but their coincidence with the external rhythm. The division of the length of the tube determines the meaning of the square signals in the weak sense that they get an ordinal position, an address. Their position within the chain is then defined and can mean, for example, a power of 2. This achieves what Hegel regarded as the origin of numbers:

"The *first* production of the number is the aggregating of the many […] each of which is then posited as only a one—numbering. Since the ones are mutually external their representation is illustrated sensuously, and the operation by which number is generated is a process of counting on the fingers, dots, and so on. What four, five, etc., *is*, can only be *pointed out*."[46]

The Automatic Calculating Engine (ACE) that Turing projected in 1945 was based entirely on mercury delay lines; due to the war and administrative hurdles the machine only went into operation at the end of 1951.[47] Its programmers achieved "optimum coding" if they read out packets of data from the tube always at exactly the right moment and sent them to another tube thus avoiding waiting periods. What it actually means to develop software more in time than in space is described vividly and lucidly in Martin Campbell-Kelly's detailed article.[48] Moreover, the engineers had to control the ambient temperature closely as any variation affected the properties of the tubes.

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45 T. Kite Sharpless, Mercury delay lines as a memory unit, in: *Proceedings of a Symposium on Large-Scale Calculating Machinery, 7–10 Jan. 1947*, ed. William Aspray (Cambridge, MA, 1985), pp. 103–109, p. 106.

46 Hegel, *Logic*, p. 206, translation slightly modified. And over a century later the Manchester Mark I. actually did represent the data as dots. This could be an indication of the clairvoyant potential of systematic thought.

47 A.M. Turing, Proposal for development in the Mathematics Division of an Automatic Computing Engine (ACE). Report to the Executive Committee of the National Physics Laboratory [1945], in: *The Collected Works of A.M. Turing. Mechanical Intelligence*, ed. Darrel C. Ince (Amsterdam, 1992), pp. 1–86. http://www.alanturing.net/turing_archive/archive/p/p01/P01-001.html.

48 M. Campbell-Kelly, Programming the Pilot ACE. Early programming activity at the National Physical Laboratory. *Annals of the History of Computing* 3 (1981): 133–162. See p. 150: "Unfortunately, optimum coding was a rather compulsive activity, and it was not always easy to have the self-discipline to stop at a point before the expenditure of programmer's time exceeded the saving in machine time."

In the transition from television to radar, a further technique of mechanical memory was developed. After the carnage of World War I., in Western democracies there was decreasing acceptance of high numbers of casualties on the battlefield, so military strategists in World War II. sought to inflict intense, long-range strikes on the enemy civil population and infrastructure from the air and the water.[49] The calculation of the trajectories of missiles was already aimed at determining the future position of an enemy target. Moreover, successful defence relied on early location of the aggressor or "foreseeing" the deployment by some other means. Since the London Blitz and the bombardment of other British cities by German zeppelins and planes during the first World War, the British in particular had a vital interest in this.

After the only partially successful attempt to concentrate the noise of targets using massive concave "sound mirrors" made of concrete and to localise the distant targets in this way, the British Government commissioned the NPL to investigate the possibility of "death rays" to destroy enemy objects.[50] In his final report in February 1935, NPL's director Robert Watson-Watt summarised the investigations of his colleague Arnold Wilkins: "Although it was impossible to destroy aircraft by means of radio waves, it should be possible to detect them by radio energy bouncing back from the aircraft's body."[51] Two weeks later Wilkins gave a successful demonstration of the system to members of the Air Ministry. By the end of 1935 the tracking technology, which employed "echoes", i.e., back-scattered pulses, had a range of over 120 kilometres. In 1936 the government decided to protect the entire east coast of England and Scotland with a huge chain of radar towers, which was named "Chain Home".

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49 Cf. Giulio Douhet, *The Command of the Air* [1921] (Washington, DC, 1983).

50 This idea, which appears latest in H.G. Wells *The War of the Worlds* of 1898, was revived by 78-year old Nikola Tesla in 1934. In an interview with the New York Times he claimed to be able to produce such rays and proposed protecting North America with an "invisible Chinese Wall of Defense" for only 2 million dollars. In a letter to the financier J.P. Morgan Jr., Tesla wrote: "One of the most pressing problems seems to be the protection of London and I am writing to some influential friends in England hoping that my plan will be adopted without delay." Cf. Margaret Cheney and Robert Uth, *Tesla. Master of Lightning* (New York, 1999), p. 144ff.

51 This phenomenon was actually discovered in 1904 by Christian Hülsmeyer; he patented his device as "Telemobiloskop". Cf. *DEPATIS*, DE 165,546, and in general Robert C. Alexander, *The Inventor of Stereo. The Life and Works of Alan Dower Blumlein* (Oxford, 2000), p. 229ff. In my depiction of the early development of British radar I follow Alexander's work.

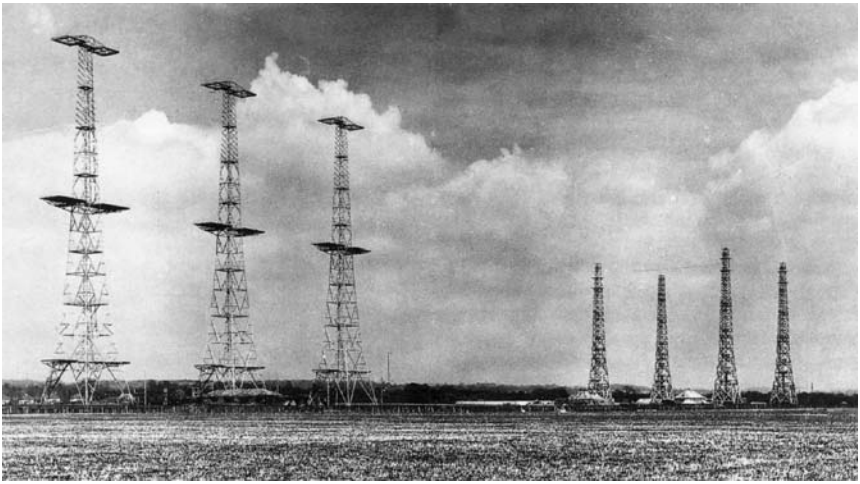

Figure 7: Radar towers on the east coast of Britain.[52]

In August 1937 the first British plane was equipped with a device to locate ships (RDF-2). Because Chain Home could not locate any low-flying objects with its long wavelength (in the metre range), in 1939 NPL in collaboration with Alan Blumlein and his EMI laboratory and team began to develop the radar system GL ("gun-laying"), which used centimetric rays. Thus the hole in Chain Home was closed with "Chain Home Low". Three receiving antennas enabled manual determination of altitude, speed, and direction of targets. The apparatus was not only equipped with a CRT, which displayed the distance on the X-axis and the strength of the signal on the Y-axis (a so-called "A-Scope"), as of June 1940 it also had a PPI ("plan position indicator"), common today, which displayed objects present inside a given radius in top view. The intensity of the echo received by the rotating antenna determined the brightness of the light dots on the display, which were plotted radially from the middle of the screen outwards.

In connection with the above, the newly formed Radar Research Group of the Royal Air Force (later re-named Telecommunications Research Establishment—TRE) developed a technology to distinguish between own and enemy planes, which was based on a transponder and was called Identification Friend or Foe (IFF). In 1939 the young engineer Frederic Williams perfected the device and

52 Richard Townshend Bickers, *The Battle of Britain. The Greatest Battle in the History of Air Warfare* (London, 1990), p. 87.

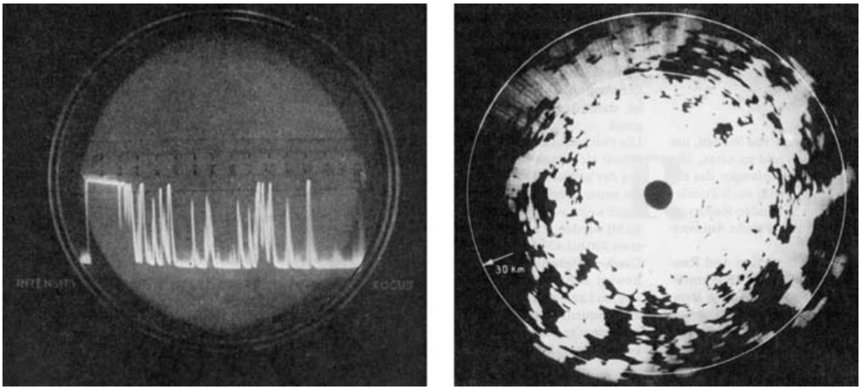

Figure 8: Display of data on the A-Scope and PPI.[53]

the electrical firm Ferranti Ltd. in Manchester produced it.[54] Williams also played a prominent part in improving mobile radar for aircraft, which tracked and intercepted other objects in the air, Airborne Interception (AI). When the technicians realised that fields, cities, and other regions equally reflected waves with individual characteristics, from the end of 1942 TRE and EMI began work on a target recognition system called H2S. Until its completion in January 1943, 90% of bombers missed their targets. After the destructive attacks on Hamburg, Leipzig, and Berlin, in early 1944 Adolf Hitler admitted that "with regard to technical inventions in 1943 the balance may have tipped in favour of our enemies".[55] In June 1943, three members of the team, including the 39-year old Blumlein, were killed in a plane crash while on a test flight.

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53 Louis N. Ridenour, ed., *Radar System Engineering. Massachusetts Institute of Technology Radiation Laboratory Series, Vol. 1* (New York, 1947), p. 165; *Enzyklopädie Naturwissenschaft und Technik*, ed. Karl-Heinz Schriever (Landsberg, 1980), p. 3514.

54 Alexander, *Inventor of Stereo*, p. 256ff. Williams and Blumlein met in the autumn of 1940; cf. p. 277: "Blumlein made a great impression upon Williams, and the latter was said to have never lost his admiration for him. Williams was particularly moved by Blumlein's approach to engineering and circuitry at EMI, and recognised with greater clarity than he had ever done before that with the right approach circuits could be designed. […] Following this meeting with Blumlein, Williams' approach was quite changed and he too adopted designability as the driving force behind his work." To understand this rather incomprehensible remark some sixty years later, one has to remember that at that time it was by no means clear how precisely the properties of electronic components, which were only just being developed, could be shaped and thus also the circuitry. See also concluding paragraphs below.

55 Ulrich Kern, *Die Entstehung des Radarverfahrens. Zur Geschichte der Radartechnik bis 1945* (Ph.D. diss., University of Stuttgart, 1984), p. 245ff. See also Bernard Lovell, *Echoes of War. The Story of H2S Radar* (Bristol, 1991).

Increasing improvement of the sensing power of radar brought problems with it, which were discussed under the headings of "permanent echoes" and "ground clutter". For stationary objects like mountains and buildings reflected the pulses, concealed moving objects, and irritated the operator by generating a lot of irrelevant information.[56] Just as with television, it was necessary to single out, or filter out of the uniformly recorded data what was of interest: "Often a radar system sees too much, rather than too little."[57] Beginning in 1940, William S. Elliott at the Air Defence Research and Development Establishment (ADRDE) worked on adapting William Percival's system to long-wave radar. A delay line stored the echo in order to subtract it from the next one received.[58] Paradoxically, it was the desire to extract moving objects from the data that led to the necessity of storing the patterns. Only when the two dimensions of the screen were extended by the third dimension of time was it possible to subtract the past signals from the

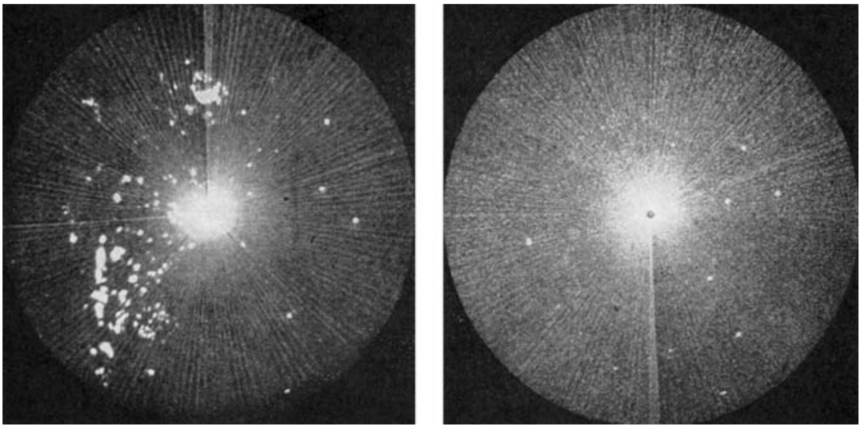

Figure 9: PPI without and with Moving Target Indication.[59]

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56 Cf. Figure 9.

57 Ridenour, *Radar System Engineering*, p. 124.

58 See National Cataloguing Unit for the Archives of Contemporary Scientists (NCUACS), *Guide to the Manuscript Papers of British Scientists. Elliott, William Sydney (1917–2000), Computer Engineer, CSAC No. 121/7/03* (Bath, UK, 2003). http://www.bath.ac.uk/ncuacs/guidee.htm#ElliottWS: "His Ph.D. studies at the Cavendish Laboratory, Cambridge, were interrupted when he joined the wartime Air Defence Research and Development Establishment at Christchurch, Hampshire, later moving to Malvern, Worcestershire. During this period he worked on radar systems, developing an interest in pulse-type electronic techniques. Projects included the use of delay lines to cancel out interference of stationary 'clutter' in radar signals, to distinguish a moving target."

present ones, and in this way to filter out what was constant and thus undesirable, i.e., that which did not cease to write itself continually and identically.

In 1942 Britton Chance from the Radiation Laboratory of the Massachusetts Institute of Technology (MIT) in Cambridge, USA, visited the British engineer Frederic Williams, who was now established at TRE, to initiate an exchange concerning progress in radar research between the two countries: "I was to learn everything they were doing, and to tell them everything I was doing."[60] In their report of 1944, which was classified information until 1960, the American engineers Robert A. McConnell, Alfred G. Emslie, and F. Cunningham, who worked on Moving Target Indication on the American side, came to the following conclusion about the British work:

"The British have used a water delay line in long-wave radar. Its success has been limited by bandwidth, attenuation, and temperature problems. [...] It is a characteristic limitation of the delay line that the system pulse rate must be precisely constant. [...] To avoid this limitation, a static storage method is needed—one which will preserve the video pattern for an indefinite period, ready for comparison with the succeeding video pattern. The television mosaic provides a means by which this may be accomplished."[61]

The authors also pointed out that the simple subtraction procedure led to "blind regions of no response whatsoever" in the radar image. Like Percival's apparatus, the technique switched off part of the image so that there moving objects could no longer be perceived. What was required, they said, was "selective elimination of ground echoes and the maintenance of a maximum sensitivity to moving targets at the same radar range".[62] The engineers succeeded in doing this by analysis of the exact wave form of echoes of successive pulses. They displayed and temporarily stored these on a CRT whose signal plate was connected to a video amplifier.[63] Through the Doppler effect, the polarity and amplitude of

59 Ridenour, *Radar System Engineering*, p. 627.

60 Andrew Goldstein, *Britton Chance, Electrical Engineer: An Oral History* (New Brunswick, NJ, 1991). The view of the IEEE, that authors may only quote from this published interview if they have written permission, is truly amazing.

61 Robert A. McConnell, Alfred G. Emslie, and F. Cunningham: *A Moving Target Selector Using Deflection Modulation on a Storage Mosaic. M.I.T. Radiation Laboratory Report No. 562* (Cambridge, MA, June 1944), p. 4. For a detailed understanding of the television set, McConnell et al. refer the reader to "Television" by Zworykin and Morton: Vladimir K. Zworykin and George A. Morton, *Television: The Electronics of Image Transmission* (New York, 1940). The pioneer of television in North America, Vladimir Zworykin, also studied under Rosing; see Fn. 38.

62 McConnell, *Moving Target Selector*, p. 1.

the echoes of moving objects changed in continuous wave radar from pulse to pulse and the echoes of static objects remained the same. The technicians measured the change as positive charge at the moment the segment of the corresponding wave was displayed, amplified it, and marked the moving targets with a light dot. In addition, the MIT Radiation Laboratory worked on systems that used the intensities of a two-dimensional area for display and calculation.[64] Instead of the direct signal on the monitor, which before had displayed the actual radar echoes received, the indicator generated arbitrary symbols.

Signals of Angels and Symbols of Nothing

From the rays received from the external world, precise algebraic processing of successive wave forms made existing objects visible that previously could not actually be seen directly. This was achieved by eradicating the traces of objects from the display that were also real but unimportant because they were constant. In this process, the engineers used a signal generator for the information that they wished to pull out and display on the CRT. Photography and television were touted as technologies that faithfully recorded reality. Radar, however, broke the seeming unity of reality and its representation apart, because it programmatically manipulated the image. The pictures were not a faithful record of the rays received; these merely represented the initial data for filtering, that is, the algebraic calculation of the image. Slowly but surely, algorithms were beginning to determine what was considered as real.

According to Baudrillard, who provides a modern paraphrase of Hegel's dialectics of the essence and its appearance, the relationship between reality and its representation develops in four stages: "1. It [the representation] is the reflection of a basic reality. 2. It masks and perverts a basic reality. 3. It masks the *absence* of a basic reality. 4. It bears no relation to any reality whatever: it is its own pure simulacrum."[65] The combination of highly sensitive sensors and imaging

63 Storing data on the radar screen merely made a process explicit that had always been present here: because it was only partially possible to shield the receiving antenna against the emitted radiance, in PPI representation the centre was always lit and not sensitive to other objects (cf. Figure 9). The "I=I", the "representation which must be capable of accompanying all other representations, and which in all consciousness is one and the same" manifested itself technically. Quotation: Immanuel Kant, *Critique of Pure Reason*, trans. Norman Kemp Smith (London, 1929), p. 153. As in the delay line, feedback produced the continuity of a signal.

64 McConnell, *Moving Target Selector*, p. 6ff.

produced by calculations resulted, as of 1941, in the appearance of "angels" on radar screens, which naturally astonished and baffled the operators. This was what they called Doppler echoes in the clear air, when pilots flying past could not identify the source. These signals hallucinated by the technical system, which correspond to Baudrillard's third, "magic" phase, fanned the flames of discussions about unidentified flying objects of extraterrestrial alien life forms in the 1950s.[66]

The director of the Radiation Laboratory, Louis Ridenour, suggested as early as 1944 that the entire body of knowledge on radar accumulated in operations research during the war be gathered together in one large work. He probably wanted to convey the impression that the main developments had taken place in the USA. Britton Chance contacted his British colleague Frederic Williams and invited him to work on two of the volumes in the now famous series, which ultimately numbered 28. To this end, the British engineer visited the Radiation Laboratory in 1945 and 1946, and there learned about the experiments of McConnell and his co-workers in which they stored radar data on CRTs. The device did not achieve the robustness necessary for application in the field and was evidently abandoned. In their contribution of 1947 to the book series Emslie and McConnell reduced mention of their own research to the sentence: "It is also possible to delay the signal by means of a 'storage tube' […] The supersonic delay line was used as a delay device in the MTI systems that have had the most thorough testing; its use is therefore assumed in what follows."[67] The Americans had overlooked the decisive fact that by using the time gained by short-term storage for refreshing the data just read, memory could be extended indefinitely: "Looking back, it is amazing how long it took to realise the fact that if one can read a record once, then that is entirely sufficient for storage, provided that what is read can be immediately rewritten in its original position."[68]

65 Jean Baudrillard, *Selected Writings*, ed. Mark Poster (Cambridge, 1988), p. 170.

66 See James E. McDonald, Meteorological factors in unidentified radar returns, in: *14th Radar Meteorology Conference*, *November 17–20, 1970* (Boston, 1971), pp. 456–463, p. 456: "Similarly, productive research on what ultimately proved to be a wide variety of types of 'radar angels' stemmed from efforts to account for peculiar echoes not identifiable as aircraft or precipitation or ground returns." The observation of radar angels later proved productive in radar meteorology. Interestingly, the engineer R.A. McConnell mentioned above began to be interested in parapsychological phenomena while he was still at the Radiation Lab. He conducted first experiments in 1947 and from then onward, concentrated exclusively on this research. In 1957, the U.S. Parapsychological Association elected him as their first president. See the Association's website at http://www.parapsych.org/members/r_a_mcconnell.html.

67 Ridenour, *Radar System Engineering*, p. 631.

With the USA's nuclear attacks on Hiroshima and Nagasaki in August 1945, World War II. came to an abrupt end, and thus also the intensive research on radar: "My interest in computers […] was directly caused by the atom bomb. Substantially overnight this event converted a mass of radar experts with endless problems for which they were seeking solutions, into a mass of experts with endless solutions and no problems, for in those days we were naive enough to believe that the end of war meant the beginning of peace."[69] In December 1946, a few months after his return from the USA, at TRE Williams successfully stored a single bit stably on a CRT.[70] At the University of Manchester, with the help of his assistant Tom Kilburn, he improved the apparatus, and in 1948 was able to represent up to 2048 "digits" on a screen. Hallucinatory signs, which only indicated angels, because there were no more enemies in the skies, thus changed into symbols of nothing; pure signs that could take on any arbitrary meaning.

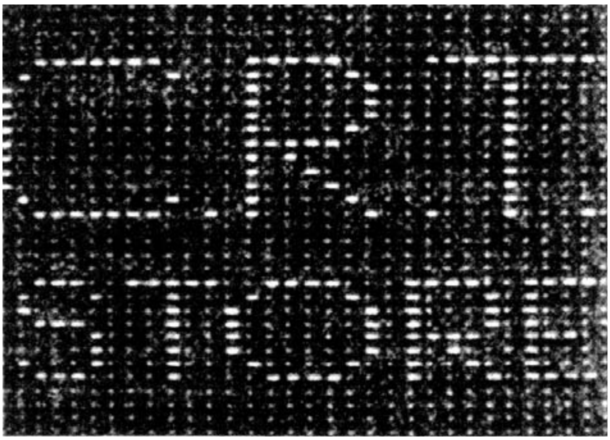

Figure 10: William's CRT Store being used slightly improperly as a visual medium.[71]

68 F.C. Williams and T. Kilburn, The University of Manchester computing machine, in: *Faster than Thought*, ed. Bowden, pp. 117–129, p. 117.

69 Williams, Early computers, p. 327. All these things—and contrary to Heraclitus—were spawned by the end of the war and of the pressure of immediate applicability.

70 T. Kilburn, From cathode ray tube to Ferranti Mark I. *Computer Resurrection. The Bulletin of the Computer Conservation Society* 1 (1990): 16–20, p. 16.

A “pick-up plate” which caught the electrons covered the front side of the screen. As in the delay line the writing head of a circuit replaced the human observer. Depending on the current state of the data charges (on or off), the bombardment of dots immediately in the vicinity resulted in signals of different polarities on the plate, which—as in McConnell’s construction—were amplified and used to re-write the information that had just been read and to switch the echo to endless. The proximity of the bombarded “pixels” produced interference and polarity changes similar to those in continuous wave radar when moving targets were observed. In William’s own words—marked by the experience of war—this resulted in the following properties of the artefact:

“(a) Either of two states of charge may be left at will at a given spot on the c.r.t. face. These states are (i) a well of full depth, by bombarding the storage spot, ceasing the bombardment and not bombarding any other spot in the vicinity, or (ii) a partially filled well, by bombarding first a storage spot, and then another spot in the vicinity before ceasing bombardment. (b) Charge distributions will be maintained for a time—a few tenth of a second—depending on surface leakage. (c) Renewed bombardment […] of the storage spot will give, at the instant of recommencing bombardment, a negative signal from the amplifier in case (a) (i), or a positive signal in case (a) (ii). (d) Bombardment of spots displaced by more than 1.33 spot diameters from a given spot has no influence on the potential distribution at that spot.”[72]

Like in battle, waves of bombardment on locations and their environs produce memories because they leave craters or “wells” behind them. What followed was the construction of the first computer, the Manchester “Baby Machine”, which in June 1948 ran a programme to calculate the highest factor of 2^{18}. It was built for the simplest of reasons: “the only way to test whether the cathode ray tube system would work with a computer was, in fact, to build a computer.”[73] From 1949 to 1950, the computer was extended and modified on a daily basis, without a master-plan to become the Manchester Mark I. It was replaced in 1951 by the Ferranti Mark I., which like William’s radar equipment was built by the Manchester firm of the same name.[74]

71 Williams and Kilburn, Storage system, p. 184.

72 Williams and Kilburn, Storage system, p. 188.

73 Kilburn, From cathode ray tube, p. 18.

74 F.C. Williams, T. Kilburn, and Geoffrey C. Tootill, Universal high-speed digital computers. A small-scale experimental machine. *Proceedings of the Institution of Electrical Engineers, Part II* 98 (1951): 107–120. Cf. Campbell-Kelly, Mark I, p. 130f.

Figure 11: The Manchester University Mark I., 1949[75]

"The fact that his [Turing's] Universal Machine had materialised mathematics allowed the reverse, to mathematise matter."[76] The inversion of the sentence is also true: the condition for representing changeable symbols lay in the fact that the scientists no longer understood natural phenomena, such as electricity, as fate and fact to be grasped descriptively, but as material that could be formed in any number of ways and in which they could write chains of simple symbols. In the first of the volumes on radar on which Williams collaborated and which bears the telling and modest title "Waveforms", he said goodbye to the traditional way of looking at waves:

"Previous treatment of waveforms has been directed mainly to sinusoids and the various manipulations that can be performed on them [...]. In approaching the subject matter of this book it is preferable to make a clean break with the traditional approach. [...] The waveforms that will be considered are not sine waves, but square waves, pulses, and even more complicated shapes."[77]

Originally used and understood as energy to power light bulbs or drive machines, and later as an analogue transmission medium, an interpretation and technology of electricity emerged which made it possible to form waves freely in different shapes and to represent symbols in them which transformed, also and even redundant echoes of love.

75 See Lavington, *Early British Computers*, p. 38: "The Mark I. was built out of war-surplus components with an enthusiasm that left little time for tidiness!"

76 Friedrich Kittler, *Unsterbliche. Nachrufe, Erinnerungen, Geistergespräche* (Munich, 2004), p. 78.

77 Britton Chance, Vernon Hughes, Edward F. MacNichol, David Sayre, and F.C. Williams, eds., *Waveforms. Massachusetts Institute of Technology Radiation Laboratory Series, Vol. 19* (New York, 1949), p. 8.

It is a good question as to why one of the very early programmes on the first computer generated letters of this kind, that is, love-letters. According to Freud, love is a phenomenon that more than any other is characterised by projections, and more than any other the love-letter is a genre that invites one to suppose the feelings and thoughts that lie behind it. Goethe, for example, once made the cynical suggestion that love-letters should be formulated in a completely cryptic way, so that the recipient could project whatever she liked into the text.[78] With the transformation of signals into signs of nothing, however, precisely this operation is necessary. Meaning can only be given to the "mad dance" of the picture dots on the Mark I. and all the computers that came afterwards from outside.[79] Without the projection that endows meaning, the computer itself merely separates and unites, writes and deletes—dots.

Translated from German by Gloria Custance

78 Cf. Johann Wolfgang v. Goethe, *Briefwechsel mit Marianne und Johann Jakob Willemer*, ed. Hans-J. Weitz (Frankfurt am Main: Insel, 1986), p. 26f.: "One would do best to write something completely incomprehensible so that friends and lovers would have complete liberty to put true meaning into it." I am indebted to Wolfgang Pircher for this information.

79 Williams, Early computers, p. 330.