Logical machines: Predecessors of modern intellectual technologies

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Abstract — **The article briefly examines the history of logical machines and describes the biographies of their inventors.**

Index Terms — **logical machine, Martin Gardner, Ramon Lull, Jonathan Swift, Charles Stanhope, Semen Korsakov, William Hamilton, Stanley Jevons, John Venn, Allan Marquand, Annibale Pastore, Pavel Khruschev, Aleksandr Schukarev, Charles Macaulay, Benjamin Burack.**

INTRODUCTION

Nowadays computers are used almost in all spheres of human activity. So the computer intellectualization became matter of topical interest today. That's why it is very interesting and edifying to know the history of machines carrying out various kinds of intellectual human work. These machines include mechanical computing devices (adding machines, arithmometers etc.), mechanical automata which can draw, write and play music, mechanical speech generators and even automata for writing poetry.

Among such devices those which are designated for solving the problems in the field of formal logic − logical machines − present the particular interest.

American philosopher and psychologist James Mark Baldwin (1864-1936) in his well-known *Dictionary* gave the following determination of a logic machine: it is "an instrument devised to facilitate by mechanical means the handling of logical symbols or diagrams" [9, p. 28]. Half century later outstanding American popular science writer Martin Gardner (1914-2010) defined it as a device designed especially for solving the problems of formal logics.

The history of mechanical, electrical and relay logical machines began by the works of famous Catalan philosopher and mystic Ramon Lull (the end of XIII century) and ended with the design of first universal electronic computers which could solve the similar problems. Actually logical machines could be considered as very first although simple and primitive model of some aspects of the process of thinking.

In his classic book [12] Martin Gardner was the first who presented the detailed review of logical machines and diagrams. Since there were appeared some new not known earlier data on logical machines [18, 27, 36]. Several small reviews [8, 10] were published after Gardner work as well. Valery Shilov in his brochure [2] and monograph [5] significantly extended and complemented Gardner's book in the part concerning logic machines (Fig. 1). But these books were issued in Russian language and it is hard for foreign reader to be familiar with new information.

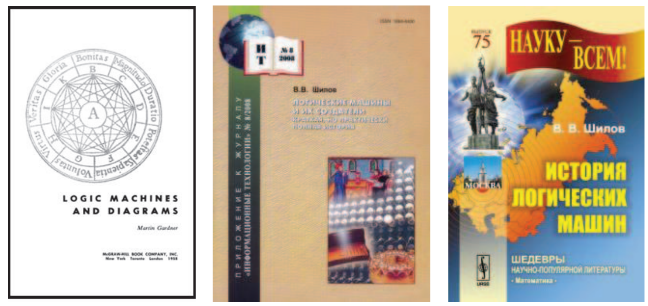


Figure 1. Three monographs on Logical Machines.

In present article we give the brief but full review of all known to the present time logical machines built before the beginning of computer era. Some of them (e.g. "virtual" logical machine of Jonathan Swift and devices of Alfred Smee and William Hamilton) Gardner described only briefly, and some (Round Demonstrator of Earl Stanhope, *machines intellectueles* of Semen Korsakov, logical machines of Pavel Khruschev and Aleksandr Schukarev, which Gardner did not know for various reasons) did not mention at all. In present paper we give only short reference on Lull, Jevons and Marquand logic machines and Stanhope's demonstrator which are well-known from other literature sources. It should be noted that Russian logic machines of Korsakov, Khruschev and Schukarev were described in details in our publications [2-5]. Other logic machines we tried to present as thoroughly as we could.

"ARS MAGNA" OF RAMON LULL

At the end of XIII century Catalonian philosopher, logic, mathematician and poet Ramon Lull (1232/35-1315) designed the device described in his tractate *Ars Magna* and some other works. It was the very first device for the mechanization of the logic conclusion derivative process. Lull was born in noble family and held a prominent position in Royal Court in Zaragoza. He became famous as the first poet who wrote in Catalan language and author of several philosophical novels. In 1265 under the influence of mystical visions he decided to devote himself to a missionary work. He traveled all over Europe, opening the missionary schools and organizing the study of Oriental languages in the universities. Lull made six missionary expeditions to Cyprus, Sicily and North Africa. According to the legend, he was stoned to death in Tunisia during the preaching of the Gospel (Fig. 2).

Figure 2. Lull in prison (left); Stoning of Lull (right).

Lull treated logics as a science for discovering the true and denial of the lie. That is why he needed a means for proof and disproof. It was provided by Ars Magna, which was understood as a logical apparatus that allows any ignorant person to discover new truths. Lull wrote that Ars Magna revealed to him in 1275 during the mystical vision on the mountain Rand (Fig. 3). So he considered it in the first turn as a means to prove the truth of Christian doctrine. He hoped that through Ars Magna Muslims and Jews should be able to comprehend the truth of Christianity.

Figure 3. Lull on the Mt. Randa.

Lull proceeded from the fact that in every field of knowledge there are several main categories, or the primary concepts, "first principles" which could form all the others. The structure of any knowledge is predetermined by the primary categories just as a system of geometric theorems derived from a limited number of axioms. Lull believed that you could get all possible knowledge of the world and discover a real connection of things by combining these categories in different ways. To facilitate such operations, Lull denoted primary category by the letters of Latin alphabet. For obtaining the combinations he allocated a set of categories on two concentric circles, separated into sectors by radial lines (he called them *camerae*). The name of category or its replacement letter was placed in each camera. It was easy to receive the table of various combinations by rotating the inner circle. Circles were made of parchment or metal and painted in bright colors to make it easier to distinguish the combinations (Fig. 4).

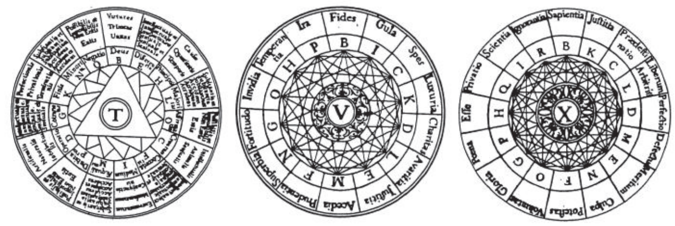


Figure 4. Figures of Lullian Art.

Lull knew that simple comparison of the concepts is not enough for conclusion. However, he hoped that by the mechanical combination of first principles it would be possible to receive "building blocks" and appropriate conclusion. Thus, according to Lull, the first task of the researcher, armed with Ars Magna knowledge, is a compilation of the comprehensive list of basic concepts. Unfortunately, the understanding that the concepts are the result of cognition and there are no some self-evident "first principles" in science had not formed for that time. So in this matter Lull was wrong. The second part of the problem, the formation of all possible concept combinations, must be performed by a machine, which ensures the completeness of a set of combinations. Here Lull is right. It is really that part of the work that could be mechanized.

Often Lull is accused in naiveté, but it is overlooked that the third part of the problem, a decision about the verity of this or that combination of terms is entirely the prerogative of the researcher, i.e. a man. Thus, the machine acts as an instrument for the analysis offering to a man more and more options and does not allow omitting some of the variants due to the errors or distraction. It is quite possible to draw, even very rough, an analogy with modern expert systems, which also act as a generator of options for solving the problem, leaving the final choice for an expert.

LULLISM: RECEPTION AND REJECTION

Lull scholastic ideas often became the subject of descendant critical statements. For example, great French writer and Renaissance humanist François Rabelais (1494-1553) in his novel *Gargantua and Pantagruel* characterized *Ars Magna* as "vanity and imposture". Francis Bacon (1561-1626) in 1623 compared it with the "fripper's or broker's shop", in which one may find "ends of everything, but nothing of worth". Réne Descartes (1596-1650) wrote in his book *Discours de la méthode* that Lull's *Ars Magna* is useful only "in speaking without judgement of things of which we are ignorant, than in the investigation of the unknown".

But at the same time Lull's ideas in the field of combinatorics, enumeration of variations and classification were very popular for several centuries. They were developed by such outstanding thinkers as German scientist, writer, theologian and alchemist Heinrich Cornelius Agrippa von Nettesheim (1486-1535), Dutch theologian and scholastic philosopher Heymeric van den Velde (1395-1460), German theologian and philosopher cardinal Nicolaus Cusanus (1401-1464), German Calvinist minister and academic Johann Heinrich Alsted (1588-1638), German polymath Athanasius Kircher (1602-1680) and many others. One of the most devoted Lull followers was Jordanus Brunus Nolanus (1548-1600) (see his Lullian figures, Fig. 5). The great Gottfried Wilhelm von Leibniz (1646-1716) was also many owe to Lull. And even Descartes in his youth was strongly affected by *doctor Illuminatus* as well!

Figure 5. Lullian figures of Giordano Bruno.

Naturally, Lull logic machine had no serious practical significance. But, nevertheless, to our opinion the great popularity of "Lull rings" stimulated the designing of various practical devices such as famous cipher disk of Italian humanist Leone Battista Alberti (1404-1472) (Fig. 6) or the so called "Denckring" of German poet and theorist of the Baroque movement Georg Philipp Harsdörfer (1607-1658), which was designated for generation of all possible words of German language (Fig. 7).

Figure 6. Cipher disk of Leone Battista Alberti.

Figure 7. *Denckring* of Georg Philipp Harsdörfer.

One more example of possible "Lull rings" influence is the device of the professor of Tubingen University Wilhelm Schickard (1592-1635). He remained the description of "Hebræa Rota", the interesting machine for checking the correctness of conjugation of verbs in Hebrew (Fig. 8).

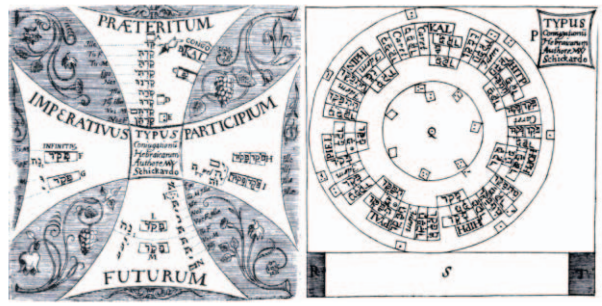


Figure 8. *Hebræa Rota* of Wilhelm Schickard.

"Logical machine" of Jonathan Swift

Jonathan Swift (Fig. 9) in the third part of his famous novel *Travels into Several Remote Nations of the World. In Four Parts. By Lemuel Gulliver, First a Surgeon, and then a Captain of Several Ships* (named *A Voyage to Laputa, Balnibarbi, Luggnagg, Glubbdubdrib and Japan*, 1726) described the grand Academy of Lagado, in which the grandiose "Project for improving speculative Knowledge by practical and mechanical Operations" was realised.

Figure 9. Jonathan Swift.

Captain Gulliver said that by this "Contrivance, the most ignorant Person at a reasonable Charge, and with a little bodily Labour, may write Books in Philosophy, Poetry, Politicks, Law, Mathematicks and Theology, without the least Assistance from Genius or Study" (Fig. 10).

It presented the frame of twenty foot square. External surface was composed of "several bits of Wood, about the bigness of a Dye", linked together by thin wires. Papers with the all known words in their several moods, tenses and declensions were pasted on them in disorder. The whole disposition of the words could be changed by turning forty iron handles. After the turn students had to find three or four words that might make part of reasonable sentence. This machine was working six hours a day and its inventor intended to collect broken sentences, “piece together, and out of those rich Materials to give the World a compleat Body of all Arts and Sciences”.

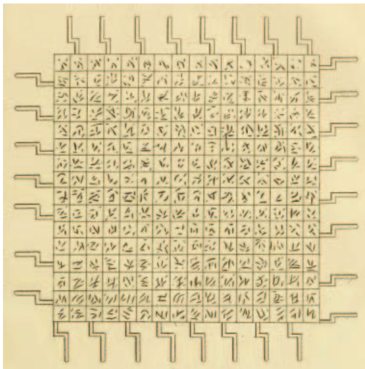


Figure 10. Logical Machine from Balnibarbi (*Gulliver’s Travels*, London, 1801).

But it is very interesting that one horizontal row of dies in this wonderful device has no handle at all (see [35]) and so is absolutely useless! In some later editions this painter’s mistake was corrected and Balnibarbian machine is shown even with more details (Fig. 11).

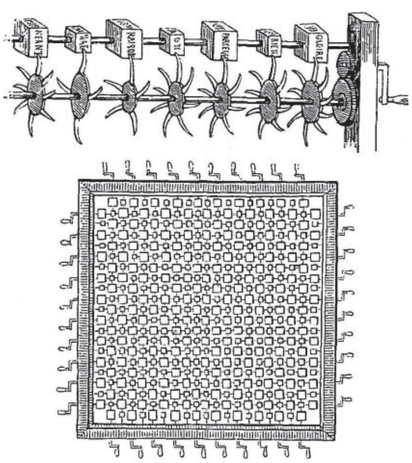


Figure 11. Logical Machine from Balnibarbi (*Gulliver’s Travels*, Paris, 1856).

In conclusion it is worth to mention that despite of Martin Gardner’s opinion [12, p. 2], the object of Swift’s parody was not Lull’s *Ars Magna*, but Aristotle’s *Organon* and Francis Bacon’s *Novum Organum*.

DEMONSTRATORS OF CHARLES, THIRD EARL STANHOPE

Charles Stanhope, 3rd Earl Stanhope (1753-1816) (Fig. 12) was probably one of the most bright and original figures of English society of the late XVIII − early XIX centuries: outstanding and prolific inventor, notable politician − the only member of the House of Lords, who expressed democratic and even radical views.

Figure 12. Earl Stanhope (by Thomas Gainsborough).

Already there were machines performed extremely complex functions. But earlier the implementation of these functions was a prerogative only of a man (let’s remember that by the second half of the XVIII century automata could move, play music, paint and even talk). So, why do not assume that it is possible to design a mechanism that reasoning like a man? Of course, man is the crown of Creation. But should he overestimate his abilities? “The machine is an anti-dote to self-conceit” – considered Stanhope.

Near 1805 Stanhope invented his famous Demonstrator. It was a small (about the size of 4×4.5×0.75 inches) mahogany block with a brass plate on the upper surface. Square opening of 1×1 inches is cut in the plate with a deepening about half an inch under it in the wooden case. There are slots on three sides of the device through which transparent plates of different colors representing premise terms can be moved in (Fig. 13).

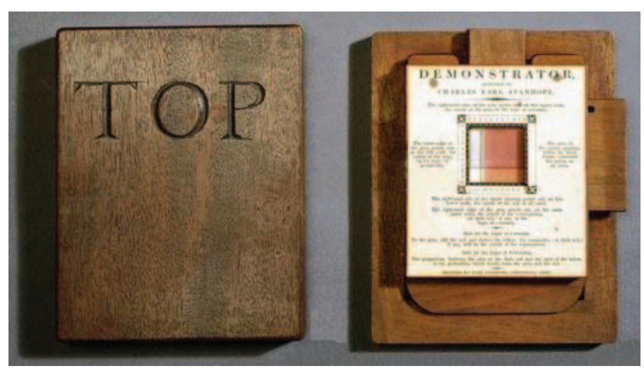


Figure 13. Stanhope Demostrator.

It could be possible to obtain the conclusions from two premises with the help of the demonstrator or verify its absence. However, the complexity of its application is comparable to the complexity of the syllogism solutions without the use of demonstrator. At the same time Stanhope’s demonstrator could be used to solve syllogisms using quantifiers “more than half”, “less than half”, “all”, “some” and numerical quantifiers. In this regard Stanhope preempted the work of Augustus de Morgan. But another kind of problems associated with probability, which could be also solved by mean of demonstrator is especially interesting.

Square Demonstrator was described many times [13, 12], but other Stanhope's logical machine called Round Demonstrator is much less known.

Round demonstrator was designed by Stanhope on his early stage of work (the first information about it appeared in one of his letters in 1801) and was intended to solve only one specific task [36]. Stanhope never recalled about the round demonstrator after 1802. Probably for this reason, it became known of its existence only two centuries later when in 1995 the London Science Museum has acquired three above described demonstrators.

Each of them consists of three concentric disks. The upper and lower disks are made of brass, and the middle one is made of glass. The front surface of the lower disc is covered with colored enamel: one semicircle is white and the other is blue. One half of the glass disk is transparent and the second one is painted in red paint (which, however, is almost erased in one of the demonstrators). Semicircular opening of 180 inches is cut in the upper disk. Figures from 1 to 5 at regular intervals in 36 inches are planted along the circumference of the disc opening. The same figures planted on the lower disc are visible through the opening. Demonstrator disk diameter is 18 cm (Fig. 14).

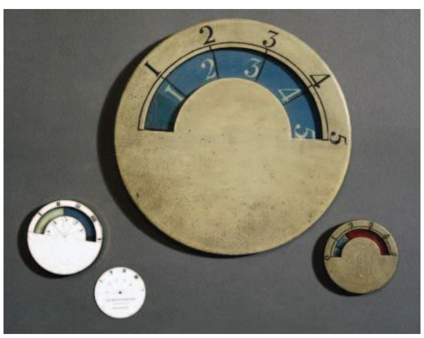


Figure 14. Round Demostrators.

Stanhope put logic on the first place among his other many occupations. But unlike some other activities and inventions the logic works of Stanhope did not find notoriety. One of the reasons for this − the fact that the book on logic "The Science of Reasoning Clearly Explained upon New Principles" he was writing for many decades and prepared for publication shortly before his death was never issued. Moreover, Stanhope considered his invention very important and asked friends to keep it a secret. Earl was very concerned about the possible appearance of "bastard imitation" to the moment when he would prepare a full publication on the subject. This publication had not taken place and it became known about the existence of a square demonstrator only sixty years after the death of Stanhope when Reverend Robert Harley (1828-1910) published the first article about the device [13]. However, it came another era and Stanhope's demonstrator did not become a sensation. Today the square demonstrator studied and described by R. Hurley is stored in the Museum of the History of Science in Oxford. Another demonstrator in 1953 was presented to the London Museum of Science by the 7th Earl of Stanhope. Two demonstrators are still stored in Chevening − former Stanhope's estate.

Machines intellectueles of Semen Korsakov

Probably inventions of Semen Korsakov (1787-1853) are one of the most remarkable discoveries in the history of computing technology for the last decades.

It was known [1] that in September 1832 collegiate councilor Semen Korsakov (Fig. 15) presented his "Report on new method of investigation" to the St. Petersburg Academy of Science. In this work he briefly described five "intellectual machines". Each of it to the inventor opinion could allow a comparing of complex conceptions from various fields of knowledge. Previously attributes of these conceptions were placed in special table.

Figure 15. Semen Korsakov.

The Academy of Science commission gave the negative conclusion and Korsakov's work was forgotten almost for one and half century. Only recently it was found Korsakov's book [17] published in St. Petersburg on French language. It contains more detailed description of his machines. For the last several years in Russia several works with Korsakov's biography and analysis of his machines were published [28, 29, 3].

Unfortunately, the publications on English language don't give full review of Korsakov work. That is why authors plan to issue the large volume on English about this unique invention in nearest time. In framework of present article we only list the names of machines, its designation and present their drawings taken from [17].

Linear Homeoscope with unmovable parts. Korsakov so described its designation: "among the large number of conceptions contained in the table it detects directly that one which contains in all details another given complicated conception. It could be up to the hundreds of details" (Fig. 16).

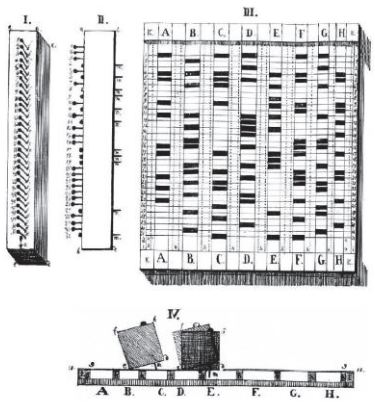


Figure 16. Linear Homeoscope with unmovable parts.

Linear Homeoscope with movable parts is designed for the same purpose but it also lists and immediately selects all appropriate and inappropriate details from given complicated conception during their contact with the details in table (Fig. 17).

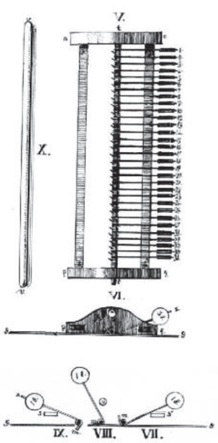


Figure 17. Linear Homeoscope with movable parts.

Flat Homeoscope. This device instantly compares two complicated conceptions which could be consisted of ten thousands of details and even more (Fig. 18).

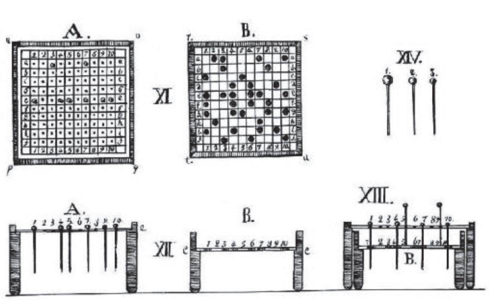


Figure 18. Flat Homeoscope.

Ideoscope implements only for several minutes the comparison of large number of complicated conceptions presented in the special table. It detects coinciding and mismatched details in two neighboring conceptions, difference between the given complicated conception and the compared conception. It also determines the details absent in both conceptions but presenting in other complicated conceptions of given table (Fig. 19).

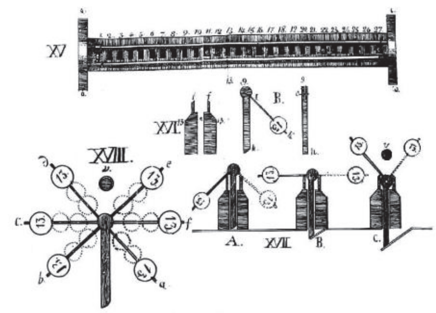


Figure 19. Ideoscope.

Simple Comparator. It gives the same four results as ideoscope but could work only with two complicated conceptions compared with each other. It accounts only several dozens of details but doesn't need the table (Fig. 20).

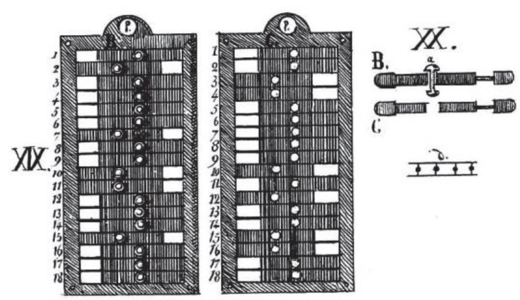


Figure 20. Simple Comparator.

"LOGICAL MACHINE" OF WILLIAM HAMILTON

The career of well-known Scottish philosopher and logician William Hamilton (1788-1856) (Fig. 21) was not very easy. His first philosophical paper was published when he was forty years. Only in 1836 he took the chair of logic and metaphysics at the Edinburgh University.

John Veitch, the first biographer of Hamilton, wrote that he was the remarkable tutor who permanently searched and found new methods to enthrall the students. Above this, Hamilton had special abilities to design mechanical devices:

"His power of mechanical contrivance was shown by certain black boards that stood on either side of the chair, and were occasionally used for exhibiting propositional and syllogistic formulae and diagrams. They have been thus described:

"One of these moves up and down in the ordinary way; another opens up, and is like a door on its hinges; and a third does neither, but stands out four-sided like a truncated pyramid on a tall pedestal of its own. This mysterious instrument, which is not unlike the trees seen in old sampler work, or the cropped yew and box of country gardens, is looked upon with a certain feeling of awe by casual lady visitors in the vacation, and timid students on first entering the class, as probably a *novum organum* of philosophy, a syllogistic machine [sic! – *Auth*.], or perhaps a dwarfed and hodded specimen of Porphyry's tree"" [33, p. 249].

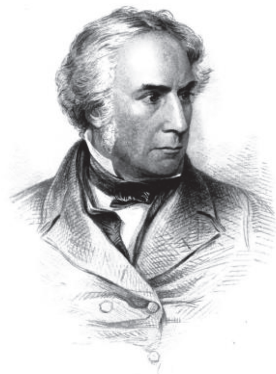


Figure 21. William Hamilton.

In his book Veitch gave the description of Hamilton mechanical device. To his opinion it could cause even the Lull envy.

"Some years later than the period now referred to, a veritable logical machine, that would have delighted the heart even of the figurative Raymond Lully, occasionally appeared in the class-room before the wondering eyes of the students. This was an ingenious apparatus, contrived by Sir William himself, for illustrating the doctrine of the comprehension and extension of notions or concepts a favorite point with him in the Logic course. It consisted of a series of hollow wooden cylinders sliding into each other, and diminishing in depth as they increased in circumference. These cylinders were arranged round an upright rod, so that their upper faces formed a horizontal plane, and the whole presented the appearance of an inverted cone. The illustration was made by first of all exhibiting the upright rod, which represented the individual, standing naked on its pedestal, and then proceeding to clothe it with the cylinders, denoting such notions as say *Greek*, *Man*, *Animal*, *Living Body*, *Body*, *Being*, when the mere supraposition showed the increasing extension with the decreasing comprehension, and vice versa.

"The vowels," says Sir William, "have been taken as affording a compendious order of subordination according to their priority and posteriority in the alphabet: A, of course, representing the *summum genus*; and z^1, z^2, z^3, &c., denoting this or these individuals. The letters in general, or the consonants, would better approximate to the possible infinity of subordinate classes; but the vowels are more convenient, and quite sufficient in number to show the variety and relations of logical classes, concrete examples of which may in any variety be applied to the abstract symbols".

The central rod was seven inches in height; the first or lowest inch was painted white, and bore the letters Z, and z^1, z^2, z^3, z^4, z^5, z^6. Above the portion of the upright rod allotted to Z was a series of six similar divisions reaching to the top, and painted successively green, purple, yellow, blue, red, black, and lettered Y, U, O, I, E, A. These represented the attributes contained in the individual Z – that is, its comprehension; and as the colours reached to the top of the rod, comprehension was thus seen to be at its maximum in Z. Extension again was shown to be at its minimum there, seeing that Z stood at the inverted apex of the cone. Now let the first cylinder, the lowest inch of which was painted green and lettered Y, be slipped over the top of the stick, it would slide down so far as to take its place immediately above the white or Z division. It thus represented a notion (say *Greek*) wider or more extensive than the individual Z (say *Socrates*), for it included under it also the little z's – z^1, z^2, z^3, z^4, z^5, z^6 (say *Alexander*, *Plato*, &c.) As, however, it only reached from Z to the top of the stick, and bore the letters U, O, I, E, A, its comprehension was seen to be less than that of Z by one division; viz., Z itself.

The second cylinder, the lowest inch of which was painted purple and lettered U (say *Man*), was now slid down over the first cylinder, the whole of which it covered, except the part allotted to the letter Y, thus showing that its extension was greater than Y, but its comprehension less, for it had under it Y and Z, but on it upwards to the top only O, I, E, A.

The third cylinder, the lowest inch of which was painted yellow, and lettered (say *Animal*), was in a similar way let down on U, and it was at once seen that its extension was greater than U, for it embraced under it U, Y, Z, while its comprehension was less, for upwards to its top there were only I, E, A.

The fourth cylinder, the lowest inch of which was painted blue and lettered I (say *Living Body*), was now let down on O, and it was seen that while its extension was increased, taking under it O, U, Y, its comprehension was decreased, for it showed upwards only E and A.

The fifth cylinder, the lowest inch of which was painted red and lettered E (say *Body*), was now let down upon I, and it was seen that the extension had further increased, for it embraced under it I, O, U, Y, Z, and upwards there was only A.

Finally the cylinder painted black, and lettered A (say *Being*), was put on to crown the whole and complete the inverted cone, and it was seen that here the extension was greatest, embracing as it did E, I, O, U, Y, Z, and, there being nothing above it to represent an attribute, the comprehension least.

Now the complete inverted cone stood before the student, who gathered up the whole lesson by noticing that the cylinders gradually lessened in breadth as they neared the base, and that the lowest of them was the least in breadth, while it supported all the increasing circles above it; wherein was symbolised the depth or comprehension of the notion, which, while it took in the least number of objects, contained at the same time the greatest number of attributes. Again, looking to the uppermost circle, he saw how it in its wide circuit embraced all the gradually lessening cylinders down to the lowest, thus symbolising the fact that the sphere of the most extensive notion, while it contains under it all the lesser or subordinate notions i.e., the greatest number of objects or classes in the same line contains in it at the same time the least number of attributes i.e., the smallest comprehension or depth. And thus the young logician obtained in a concrete symbol a summary glimpse of the very abstract doctrine of the nature and relations of concepts" [33, p. 249-252]. Logical machine of Hamilton is presented on Fig. 22.

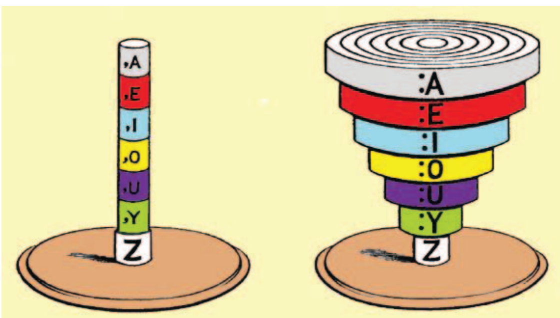


Figure 22. "Logical Machine" of William Hamilton.

Hamilton actively worked in the field of logic only for several years. After the seizure in 1844 he forever ceased scientific and pedagogical activity. The most important work of Hamilton (*Lectures on Metaphysics and Logic*, vol. 1-4, Edinburgh and London, 1860) was issued posthumously. But his contribution in science was very significant. For example, exactly the famous polemic between Hamilton and Augustus de Morgan caused George Boole to complete the work *The mathematical analysis of logic, being an essay towards a calculus of deductive reasoning.* This book became one of keystones of modern mathematical logic [19].

Thus, seldom mentioned Hamilton didactic mechanism (Veitch called it "veritable logical machine" [33, p. 249]) must take its own, though modest, place in the history of logic machines.

VIRTUAL LOGICAL MACHINES OF ALFRED SMEE

In the middle of the XIX century the reputed English scientist Alfred Smee (1818-1877) (Fig. 23) developed the theory, which he called electro-biology. Its purpose was to study the effect of electrical phenomena on the functioning of the human body. Smee was primarily interested in the connection of electrical stimulation of the nervous system and brain work. Later his research in this area became more philosophical than natural-scientific, and he published the book *Process of Thought Adapted to Words and Language* [31], in which particularly proposed a plan to build an artificial system of mental conclusions modeling inner mechanisms of human brains. Though Smee based the knowledge of these mechanisms (at the time virtually unknown) on his own ideas of what they might be. Later this small treatise with a few additions was included into the monograph *The Mind of Man: Being a Natural System of Mental Philosophy* [32].

Figure 23. Alfred Smee.

According to Smee, the mental image showing concepts or objects of the external world arose in the minds of humans due to electrical effects on the elements of the nervous system (nerve fibers), and each image was represented by some combination of fibers. This combination was stored, and later when the same object was being recognized, it was retrieved from memory. To make judgments it means to recognize the relations of agreement or disagreement between two concepts, two separate subjects or a concept and a separate subject, comparing them with each other. To find relations between concepts (i.e. actually for simulating the operation of brains), he proposed to use two original mechanical logical machines and described them.

Relational Machine (Fig. 24) was intended for presentation and comparison of concepts. Unfortunately, his explanations are very concise and unclear. In general, one can understand that Smee conceived his device as a collector of knowledge, with capability to add new facts, concepts, etc. Based on rules derived from the laws of thought, its internal state changed, taking into account and showing all the relations between new and previously presented concepts. If this collector of knowledge were universal and all-inclusive, then, according to Smee, "it is thus apparent that this mechanism gives an analogous representation of the natural process of thought, as a human contrivance can well be expected to afford".

Of course, Smee knew that it was impossible to implement his idea in full scale: "Supposing that the machine could be made sufficiently extensive for all practical purposes, yet the labour of employing it would be so great, that persons would soon rely upon the abilities which it has pleased Providence to give to them, and not seek assistance from extraneous sources".

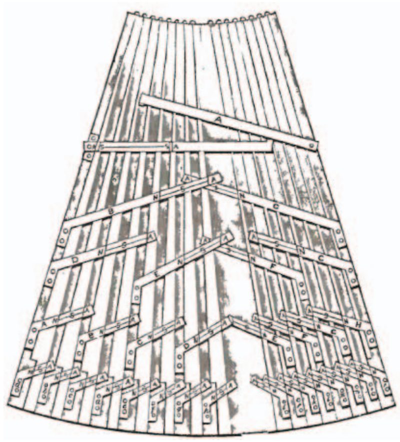


Figure 24. Relational Machine.

The second machine, proposed by Smee, *Differential Machine*, was intended to compare two concepts. The machine was a two-piece rectangular frame (Fig. 25). One of the parts had a slightly shorter length, and therefore could be slided into the second part. Along the long sides of the frame rectangular bars of different lengths were laid, representing the properties of some concepts. Bar of one unit height corresponded to the presence of property and a bar of 2 units height – its absence. At the top of the other frame for the presentation of other terms bars of height of 4 units were used, meaning the absence of property. Smee supposed that such device could be used in many cases. For example, he cited examples of comparisons of testimonies and decided that «the mechanical judge» in the civilized world would produce a sensation.

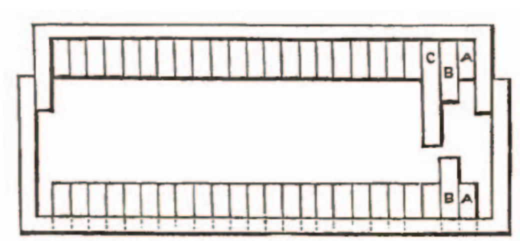


Figure 25. Differential Machine.

Books of Smee gained some popularity among psychologists and physiologists, but were not recognized by mathematicians and logicians. So, Stanley Jevons learned the ideas of Smee only after invention of his own logical machines. Jevons said: "So far as I can ascertain from the obscure descriptions and imperfect drawings given by Mr. Smee, his Relational Machine is a kind of Mechanical Dictionary, so constructed that if one word be proposed its relations to all other words will be mechanically exhibited. The Differential Machine was to be employed for comparing ideas and ascertaining their agreement and difference. It might be roughly likened to a patent lock, the opening of which proves the agreement of the tumblers and the key".

Perhaps the unclear descriptions of Smee's logical devices mentioned by Jevons prevented their further investigation. For example, Martin Gardner only mentioned them, calling the book of Smee "odd" [12, p. 144]. It seems, that our papers [3, 30] are the only publications on these machines.

Logical machines of William Stanley Jevons

The name of the famous English scientist William Stanley Jevons (1835-1882) (Fig. 26) is now rarely mentioned in connection with the history of computing. It is extremely unfair because actually the modern Boolean algebra and algebra of logic in its present state were formed due to Jevons works. Only this would have been enough to put Jevons in the pantheon of computer glory! But beyond that, he was the first who built a real logical machine. The word "machine" should be emphasized because for the devices of Lull and Stanhope is still difficult to apply this determination.

Figure 26. William Stanley Jevons.

More precisely, his first invention in the field of logic had not yet been the machine. It was the so-called *logical slate*, ordinary blackboard on which there were written on the left all the possible combinations of logical variables and their negations for the number of variables from one (two variants) to six (64 variants). Jevons said that he used logic slate for 12 years and it saved him a lot of time and allowed to avoid many mistakes in calculations. However, he also wrote that the logical slate was difficult to use when the number of variables exceeded 6.

Later Jevons invented another device for educational purposes which he called *logical abacus*. It was the ordinary school board installed with a slope. It had four horizontal shelves of the same length. Plates with written premises were placed on the top shelf (the plates could also contain except the letters signs of operations, for example equality). Thin wooden rectangular plates with written letter combinations symbolizing the logical variables and their negations were installed on the second shelf from the top. Total number of such plates was 16 (ABCD, aBCD, ..., abcd). Several plates having a common feature could be picked up at once with the help of a long ruler. For example, it could be possible to divide A and negation of A by removing all 8 plates corresponding to the combinations with symbol a. Finally, only those combinations of variables compatible with all given premises were remained on the second shelf. Jevons logical machine built in 1869 is probably the most famous of all logical machines. Outwardly it looked like a small piano (it height was about 90 cm) with keyboard of twenty one key. The similarity was strengthened by a cap covered the keys. The letters symbolizing the terms in the premises are planted on sixteen keys (Fig. 27). Its construction and principles of operation are described in many publications [14, 15].

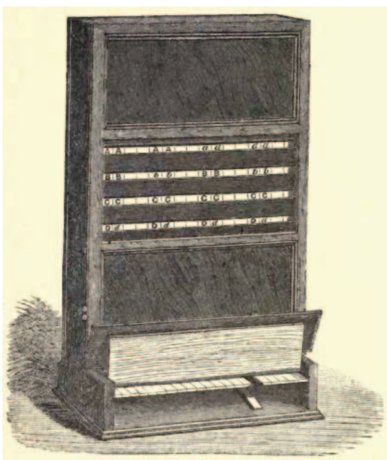


Figure 27. Logical Machine of Stanley Jevons.

Compared with the device of Ramon Lull Jevons machine has a distinct advantage. It really, though partially, mechanized the process of logic conclusion. However, the result of conclusion (more precisely, the result of removal of all combinations which do not satisfy to initial premises), must be formulated and explained as it was being done by Catalan thinker. Only man could do this.

Machine's significant disadvantage was a limited capacity. It was intended to derive the conclusions from the premises containing no more than four terms. However, Jevons believed that it was hardly necessary to solve formal logic problems in a real life. That is why he considered his machine just a tutorial means for better understanding of the process of logic conclusion. However, Jevons machine (which is now kept in the Museum of the History of Science in Oxford) became the first and rather successful variant of mechanization of logic conclusion. Moreover, it showed the goal to achieve − modeling of human thinking.

Logical machines of Allan Marquand

All who worked in the field of logical machines after Jevons were under his strong influence. American Allan Marquand (1853-1924) (Fig. 28) was not the exception. But he, however, was able to overcome this influence and build one of the most interesting and original logic machines.

Figure 28. Allan Marquand.

Marquand's name is still recalled with deep respect in the American artistic environment. He studied theology at Princeton, then he studied in Berlin for a year and in 1877-80 he taught ethics at the famous Johns Hopkins University. When in 1881 he was asked to return to the *alma mater* and become a professor of art history Marquand took it without hesitation. He developed the first academic program on this subject. Two years later he organized and headed the Department of the History of Art, perhaps the first in the United States. As a result he wrote several capital monographs on Italian Renaissance painting and Greek architecture, which still have not lost its scientific significance.

Marquand began study logic thanks to a meeting with the outstanding American logician and philosopher Charles Sanders Peirce (1839-1914). They met, most likely, in Princeton, where Pierce occasionally was invited to lecture on logic and philosophy. They closely contacted when Marquand taught at Johns Hopkins University. In addition, they maintained an active correspondence discussing many problems related to the design of logical machines.

The first result of Marquand's interest in logic was the mechanical device (a kind of logical machine) for demonstration of syllogism options built not later than 1881 [22]. It comprised of three cylinders of various diameters. Cards with different variants of classic syllogisms premises were planted on the two upper cylinders and the third cylinder had the cards with different variants of the syllogism conclusion. There were three openings on the front side of the device and by handle rotation the cards in turn appeared in the openings. It was sufficient eight full turns of the handle for sorting all premise variants (Fig. 29).

To Marquand own admission his first personally built in 1881 logical machine (it did not survive) completely copied the prototype. However, the machine worked extremely unreliable and at the end of the year he had to seek the assistance one of his colleagues. At the beginning of 1882 the second Marquand logical machine was ready.

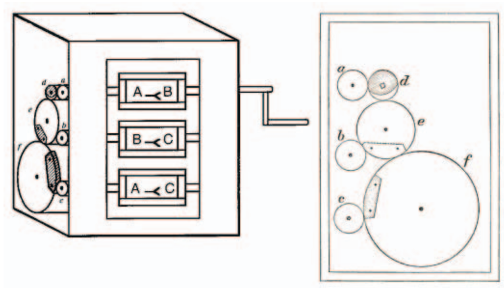
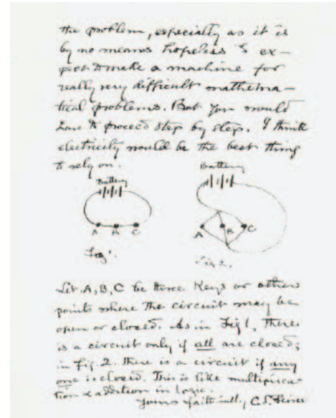


Figure 29. Syllogistic Machine of Allan Marquand.

Made of mahogany, it looked like as Jevons machine and also was designated to simplify logical expressions with no more than four terms (Fig. 30). Marquand was able to reduce it dimensions compared to the prototype (the size of the machine base was 21×15 cm with a height of 32 cm). If the basis of the Jevons logical machine were sliding rails the Marquand machine had 16 switches corresponding to all possible combinations of four logical variables. Marquand managed to reduce the number of keys from 21 to 10. Even only for this reason it was preferable to Jevons machine. The description of the design and operation of Marquand logical machine may be found in [12, 18, 23, 24].

Figure 30. The second Logical Machine of Allan Marquand.

After designing the second mechanical logic machine Marquand did not try to improve its construction. However, the discussion of logical problems with Pierce continued. In one of his letters to Marquand Pierce advises: "It seems to me that the best thing is to use the electricity" and presents two simple circuits with three keys (in one circuit they are connected in series and are parallel in the second), see Fig. 31. Pierce writes that the current flows in first circuit only if all three keys close it and in the second, if the circuit is closed at least by one key. He draws attention to the similarity of this performing with the operations of logical addition and multiplication, respectively.


the problem, especially as it is
by no means hopeless to ex-
pect to make a machine for
really very difficult mathema-
tical problems. But you would
have to proceed step by step. I think
electricity would be the best thing
to rely on.

Let A, B, C be three keys or other
points where the circuit may be
open or closed. As in Fig 1, there
is a circuit only if all are closed;
in Fig. 2. there is a circuit if any
one is closed. This is like multiplica-
tion & addition in Logic.
Yours faithfully, C. S. Peirce

Figure 31. The letter of Charles Sanders Pierce to Allan Marquand.

Near 1885 Marquand made the first in the history project of electromechanical logical machine. Its drawing kept in the Marquand archive (Fig. 32) and was published only in 1953 [25]. Apparently, Marquand did not try to bring his project to life. The lack of data makes it possible the different interpretations of the scheme [27]. But in any case this project occupies a unique place in the history of logical machines in particular and computer technology in general. One could only guess what the development of computers would have been if Marquand implemented his project, and relay machine got the deserved fame.

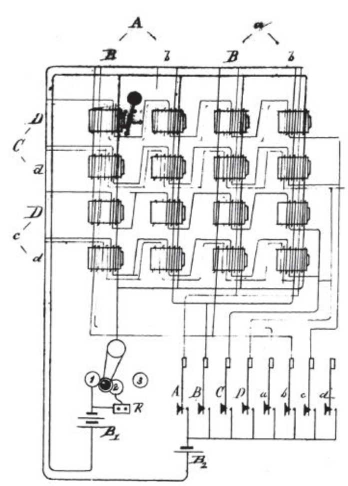


Figure 32. Relay Logical Machine of Allan Marquand.

SYLLOGISTIC CYLINDER OF HENRY CUNYNGHAME

The name of Sir Henry Hardinge Cunynghame is seldom remembered in relation with the history of logic machines. Gardner devoted only one page to this scientist. Nonetheless, the bright person of this man and his contribution to the science (including the mechanization of reasoning) is worth to mention.

Cunynghame was born in 1848 in the family of highest English aristocracy. Being the youngest son Cunynghame according to the family tradition choose a military career. However, he soon changed it and became a lawyer. Then he got involved in economics and was one of the most noticeable high rank officials for 40 years. Besides that Cunynghame was very close to the artistic circle of Pre-Raphaelites and was a good painter himself.

He wrote several books (each became the notable event for that time): monograph on the theory of electricity and practice of electrical lightning (1873); eight hundred page work about British patent law (1894), three books on history and enamel technology etc. He investigated methods of time measuring from antiquity till the beginning of XX century (1906, republished in 1970), made deep analysis of the greatest philosophers from Plato and Aristotle. Especially interesting was his book *Geometrical Political Economy* (1904) in which Cunynghame firstly used convenient and visual diagram method. Economists highly appreciated his not very big but important contribution to their science. It is sufficient to say that Cunynghame's obituary was written by the great John M. Keynes (*The Economic Journal*, vol. 45, No 178, June 1935, pp. 398-406).

But Cunynghame was not only a theoretician but had the evident engineering talent. It is known not less than his seven his patents granted in Great Britain and USA. Cunynghame proposed the modification of various devices such as electric clocks, aneroid barometers, hygroscope, furnaces for enameling metals, et al. Moreover, in 1885 Cunynghame published the description of mechanical method of solving quadratic and cubic equations with real or impossible roots. Before that in Cambridge he invented a device for drawing a grid of rectangular hyperbolas on the blackboard (it was used by Alfred Marshall for many years).

Cunynghame inventions related with logics were also done at that period of time. The evidence of this fact are two undated Cunynghame's letters written after 1878 year to Stanley Jevons. In these letters he mentioned about the invented logic machine, which he sent to Jevons for evaluation (to that time Jevons was the designer of the first and only one logic machine in the world), though it seems that Cunynghame worried mostly not about technical details but philosophical problems. He tried to understand whether his machine could execute logical operations and "has the *machine* done the work or have *I*. Is this not merely a mechanical register of results otherwise arrived at. I fear it is" [20, p. 141].

Probably, the invention of syllogistics cards (Jevons wrote in details about them [16, p. 108-109]) was made before the designing of machine. The set of these cards is rather convenient method for learning of syllogistics. To Jevons opinion "this device, though hardly perhaps to be called a syllogistic machine, is probably the nearest approximation to such a machine is possible" [ibid., p. 108]. However, Cunynghame made a step to the mechanization of the process of syllogistics inference. He manufactured mechanical device designated for the same purpose. The principle of Cunynghame syllogistic cylinder is exactly the same, but "considerable ingenuity was needed to combine the card together into cylinders in the best way" [ibid., p. 109]. The device consists of two cylinders – internal with premises on its surface and external one with conclusions on the surface. Both cylinders are rotating on the common axis. One complete revolution of external cylinder moved by a handle permits to get all possible syllogism variants. Probably, Cunynghame's machine was similar to the Marquand machine for syllogistics conclusions.

Unfortunately, Cunynghame did not publish his results in the field of logic machines (Jevons characterized them as ingenious and interesting devices [ibid., p. 108]). The drawings and machine itself (if it of course was really built at all) did not remain. According to Gardner's report [12, p. 119] Cunynghame presented to the Scientific museum in South Kensington one more his logical machine in 1885. It reminded round slide rule and consist of two cardboard disks. Eight premises variants were written along the circle of large and small disks, the same one that on large and small cards. The conclusions, corresponding to the combination of two premises, opens in the windows cutting in the smaller disk during it rotation. Perhaps, this Cunynghame's device was the closest approximation to the Lull one!

It is possible that a half century later the similar logic machine could be built by well-known American psychologist Clark L. Hull (1884-1952) (Fig. 33).

Figure 33. Clark L. Hull.

In one of his articles he wrote that "it has been found possible to construct a relatively simple mechanism of sliding disk segments of sheet metal which will solve automatically, *i.e.*, exhibit the conclusions logically flowing from all of the known syllogisms and will automatically detect all of the formal fallacies" (*Psychological Review*, vol. 42, May 1935, p. 219). Hull did not publish the description of this device. Thus, the details of his construction are still unknown.

LOGICAL-DIAGRAM MACHINE OF JOHN VENN

The English mathematician John Venn (1834-1923) (Fig. 34) was very original person. Some time he was a priest for a long period but then he renounced a dignity. He considered that it is impossible to be a priest and the scientist simultaneously. Venn liked many kinds of activity: he was passionate tourist and alpinist, good botanist and excellent speaker. Logic was his first and long hobby (later it was changed for a history). In 1881 Venn published the book *Symbolic Logic* [34]. By the way, exactly he suggested for the first time to use this term, which was further common accepted. In this book he proposed a new means for visual presentation of mathematical logics and set theory conceptions – the so called Venn diagrams. It was important contribution to the development of mathematical logic.

Figure 34. Reverend John Venn.

Venn treated logic machines very skeptically and presented two arguments for this. First one to his opinion is that in practice the problems which demand the application of logic machine are very seldom, because "It is rather we who look about for complicated examples in order to illustrate our rules and methods". Moreover, he considered that "It does not seem … that any contrivances at present known or likely to be discovered really deserve the name of logical machines", because the work it does is only a small part of the general process of reasoning [34, p. 119-120].

Venn also negatively said about the potential of Jevons machine. But at the same time he proposed his own logic machine, also he preferred to call it as *logical-diagram machine*. Venn stated that despite its simplicity his machine could fulfil all the specific logic machine functions. It was designated for the solving of problems with four logical variables as well as Jevon's machine.

Brief description of Venn's machine and its drawing (Fig. 35) is presented in [ibid., p. 122-123].

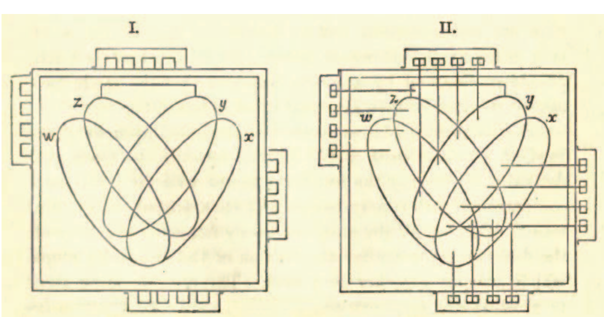


Figure 35. Logical-diagram machine of John Venn.

Every of 16 segments on the drawing is a part of wooden elliptical cylinder of 1.5 inch height (the half of device depth). Before the start of the work all the segments are installed on the same level along with upper device plane. They are fixed in this position by the metal spokes. For removing of any part of the surface it is sufficient to pull out the appropriate spoke and its segment falls down. It only needs to turn the device face down and push inward all the spokes for segment fixation to prepare machine to work again.

Venn considered the small dimensions of his machine (approximately 6×6 inches with the depth of 3 inches) as an unexcelled advantage. However, it is easy to see that Venn's machine, which in fact is a spatial analogue of his diagrams, has not any advantages with viewpoint of work speed. Indeed, it needs less time to draw the appropriate diagrams on paper and color the segments then to set machine initially and to manipulate it further. Similar, it is more simple and faster to correct the possible mistakes on the paper.

Unfortunately, Venn's logic machine was not very successful and in fact it was not remembered today. But Venn's diagrams are popular and widely used.

PAVEL KHRUSCHEV: RUSSIAN LOGICAL MACHINE

The first in Russia logic machine was built by well-known national physicist and chemist Pavel Khruschev (1849-1909). He was born in St. Petersburg in the family of prominent government official and rich landowner. Pavel received the excellent education and worked several years in the leading German universities. After returning in Russia he organized scientific laboratory in his own country estate in the village Karasevka near Kharkov city. To the end of XIX century this laboratory was one the most advanced and well equipped laboratories in Russia capable to carry out various experiments and investigations (Fig. 36).

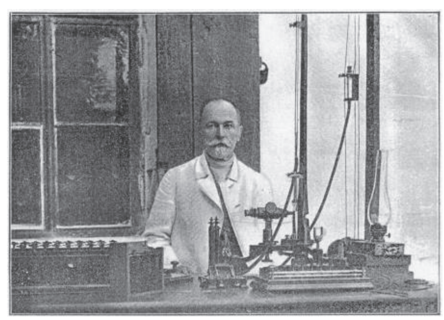


Figure 36. Pavel Khruschev in his Karasevka laboratory (1906).

There is no much information about Khruschev logic machine. Most probably that Khruschev acquainted with the work of Jevons [15] not earlier than at the end of 1896 or at the beginning of 1897. Translation of this book was well known in Russia to this time. The building of logic machine could be start in the middle of 1897 in Karasevka and ended not later than the spring of 1898. Khruschev intended to use this machine during his lectures in Kharkov University. But there are no any references on this machine not only in Khruschev's own publications but in the memoirs of his colleagues and students. It seems that Khruschev did not give special significance to his machine. He treated it only as an accessory tutorial instrument for his lectures. That is why this invention was not mentioned by scientific society.

After the death of Pavel Khruschev in 1909 his logic machine with the other equipment of Karasevka laboratory was handed to the department of non-organic and physical chemistry of Kharkov University by his widow. Most likely this unique device would have been forgotten. But it did not happen due to another outstanding Russian scientist in the field of physics and chemistry whose name is Aleksandr Schukarev. We owe to him all the information about Khruschev's machine we have today including the only one known photo (Fig. 37).

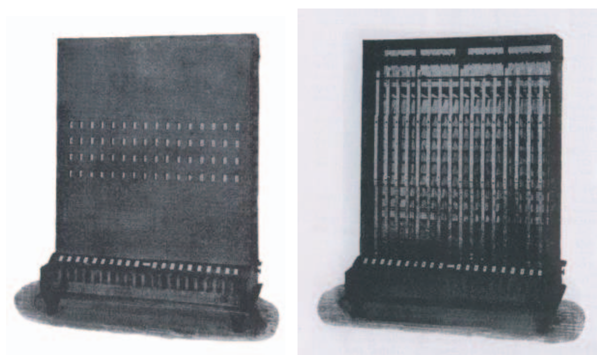


Figure 37. Logical Machine of Pavel Khruschev (from [6, p. 51, 52]).

ALEKSANDR SCHUKAREV: THE INHERITOR OF PAVEL KHRUSCHEV

Alexander Schukarev (Fig. 38) was born on 2 November 1864 in Moscow in the family of petty officer. In 1889 he graduated from Moscow University, Faculty of Physics and Mathematics. In 1906 Schukarev defended M.Sc. dissertation and in 1909 Doctor of Science dissertation. Then he was elected as a professor of general chemistry of Ekaterinoslav High Mining School and then after two years of work he became the professor of Kharkov Technological University. Almost all his further scientific activity was dealt with this University.

Significant part of Schukarev scientific publications was devoted to his main specialty – physical chemistry but he also was interested in the problems of logic, methodology of science and philosophy.

During his work in Kharkov University Alexander Schukarev saw for the first time in one of physical-chemical laboratories the logic machine created by Pavel Khruschev. It was very interesting for Schukarev who was developing the problems of logic and theory of cognition. As he said, he had "inherited" the logic machine from Khruschev.

Figure 38. Aleksandr Schukarev.

Khruschev machine as it prototype – Jevons logic machine – was constructed as a high drawer with keyboard on which separate messages were set and indicator board with the openings in which the possible terms combinations were formed.

Schukarev made the improved variant of Jevons logic machine which description (unfortunately also very laconic) was given in his article "Mechanization of thinking (Jevons logic machine)":

"I simply gave the instrument the smaller dimensions, made it from metal and eliminated some pretty decently I must confess constructional defects. The further step forward was connecting the special illuminated screen to the instrument. The work of machine is transmitted to this screen and results of "thinking" appear not in form of symbols as on Jevons machine but in ordinary verbal form" [7, p. 826-827].

Schukarev ended his description of Jevons logic machine principle of work so:

"In my device, the rear rods connect electrically with special screen consisting from 16 horizontal racks, each bearing two ordinary electrical lamps. List of transparent paper is hanged before these racks, and on this list the same combinations as on rods in ordinary words are written by drawing ink. For example, if A designates "silver", B – "metal", C – "current conductor", O – "possess free electrons" than in the first upper line of illuminated screen against the first rack with the lamps the words "Silver – metal, current conductor, possess free electrons" will be written.

In null machine position, all screen lamps are lit and all combinations illuminated behind could be seen by audience very clear. After installing definite sentences, some rods are lifted up and appropriate racks are deactivated. Only such combinations of concepts which compatible with given settings remain illuminated" [ibid., pp. 827-828].

Undoubtedly, the character of modifications made by Schukarev (though he specified that they "were not of principle character") allows concluding that he built just new machine and did not simply improve Khruschev machine (Fig. 39). He wrote that machine "at present time [in 1912-13 – *Auth*.] is the property of Kharkov University" [6, p. 49]. That is why we may suppose that after construction of machine the inventor returned its prototype to the University.

Unfortunately, the fate of original Khruschev machine is unknown.

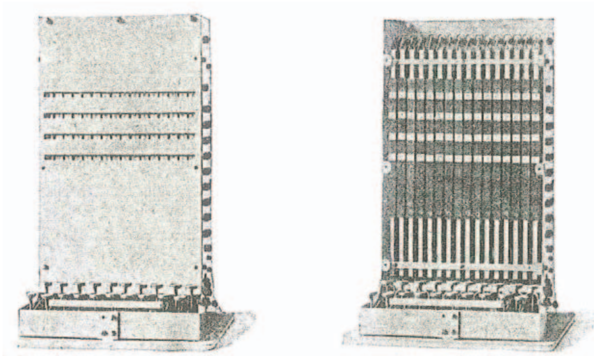
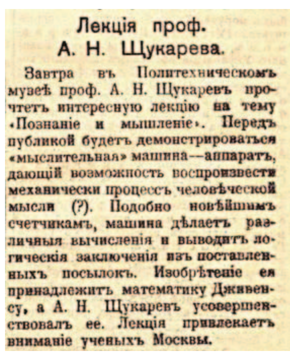


Figure 39. Logical Machine of Aleksandr Schukarev.

Schukarev repeatedly gave public lectures on the theory of cognition using the logic machine for supporting his opinions and theoretical statements. Until 1917 Schukarev demonstrated his machine not only in Kharkov but in others cities of South Russia. In April 1914 he gave lectures in Moscow. It is known several newspaper advertisements about these lectures. You may see one of these advertisements on the following Fig. 40.



Лекція проф.
А. Н. Щукарева.

Завтра въ Политехническомъ музеѣ проф. А. Н. Щукаревъ прочтетъ интересную лекцію на тему «Познаніе и мышленіе». Передъ публикой будетъ демонстрироваться «мыслительная» машина—аппаратъ, дающій возможность воспроизвести механически процессъ человѣческой мысли (?). Подобно новѣйшимъ счетчикамъ, машина дѣлаетъ различныя вычисленія и выводитъ логическія заключенія изъ поставленныхъ посылокъ. Изобрѣтеніе ея принадлежитъ математику Дживенсу, а А. Н. Щукаревъ усовершенствовалъ ее. Лекція привлекаетъ вниманіе ученыхъ Москвы.

Figure 40. The announcement of a Professor Schukarev lecture (*Moskovskie vedomosti*, April 18, 1914) – *published for the first time*.

Public presentations and improvement of his machine Schukarev continued after October revolution until the 1925. It is known that besides regular demonstrations of logic machine in Kharkov, Schukarev showed it in Moscow and Leningrad. Logic machine as well as ten years ago caused the great interest of spectators.

But Schukarev's philosophical ideas including ideas in the field mechanization of thinking caused strong critics of communist ideologists. That is why he did not demonstrate his logic machine after 1925. Schukarev died on 1936. Probably, logic machine was destroyed during WWII.

Schukarev's logic machine as its predecessor was forgotten for a long time. Russian logic machines were remembered at the beginning of 1960 years, possibly on the wave of common enthusiasm by cybernetic ideas. That is why it is clear that Gardner did not describe it in his work. He simply did not know about it to the moment of writing the book.

Today, Pavel Khrushchev and Aleksandr Schukarev finally gained deserved recognition and got the worthy place in the pantheon of Russian science. Schukarev memorial plaque was erected on the wall of Kharkov Polytechnic Institute on 21 October 2011 since of 75 years of his death.

It is the short description of Schukarev's life and activity. More detailed and interesting information about this original and talented scientist you may find in our article [37].

MACCHINA CAPACE DI RAGIONARE OF ANNIBALE PASTORE

At the very beginning of XX century the Italian logic and philosopher Annibale Pastore (1868-1956) (Fig. 41) built original mechanical logical machine (reasoning machine − *machine capace di ragionare*). It was designated for modeling of syllogistic conclusions (Fig. 42).

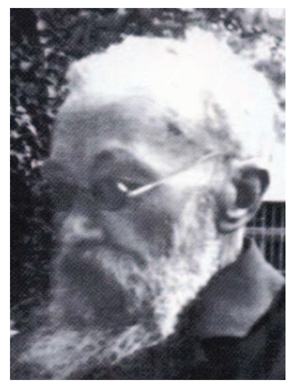


Figure 41. Annibale Pastore.

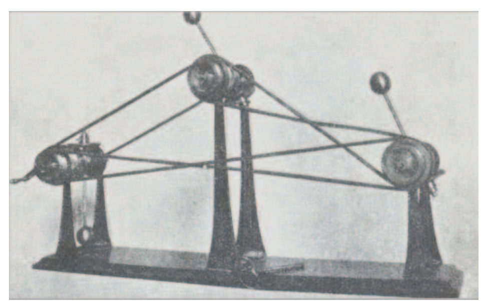


Figure 42. Logical Machine of Annibale Pastore.

Three groups of wheels are the basic part of construction which corresponds to the subject, predicate and middle syllogism term. Each of these groups contains three coaxial wheels − the large one representing the "all" of its class and two small wheels representing "some" of the same class. Wheels are joined with the endless belts. Various kinds of belts location correspond to the appropriate terms relations. So, for representing a universal affirmative proposition "All A is B" the belt joins the large wheel of A with the small wheel of B so that, when A is turned, B will turn in the same direction. Similarly, for representing particular positive “Some A is B” the small wheels of A and B joined by the uncrossed belt. The rotating of the wheels in the opposite directions appropriates to the universal negative. Universal negative “No A is B” and particular negative “Some A is not B” is set as following: the crossed belt joins the large wheels of A and B and small wheel of A with large wheel of B accordingly.

If the belts represent a valid syllogism, cranking wheel A will cause all the wheels to rotate smoothly. If the wheels cannot rotate than the syllogism is not valid.

It should be noted the mechanical complexity of this construction. It is clear that if large wheel of A rotates it must move two small wheels because they are the parts of same class. However, if the small wheel rotates than the large wheel must remain motionless because all of the class does not necessarily has the characteristics of its part. Moreover, in order to ensure the possibility to represent simultaneously “some A is B” and “some A is not B” coaxial small wheels must rotate in opposite directions while the large wheel remains stationary (since we know nothing about all of A). That is why Pastore machine has the system of differential gear.

With the help of this machine 256 variants of the belt arrangements could be tested that correspond to 256 possible combinations of syllogistic premises and conclusions. According to Pastore there are 32 valid syllogisms. Wherein the variant

Some A is B
Some B is C
Some A is C

in given mechanical realization is valid. At the same time of the 24 traditionally valid syllogisms, a few which require the assumption of non-empty classes are not validated by the machine [26].

In whole, it might be said that Pastore machine is more the illustration to the syllogism solving than the convenient and reliable instrument for obtaining conclusions from two premises. It is worth to mention that unlike all other known logic machines, which are the machines of discrete action (i.e. digital), Pastore machine could be called as the machine of continuous action (i.e. analogue type).

It should be also noted that though Gardner wrote that “the device … was constructed in 1903 with the aid of physics professor Antonio Garbasso. It is explained in preposterous detail in Pastore’s work … published in Turin, 1906” [12, p. 114], but in Pastore’s monograph it is said that to this year it was only the emergence of idea of logic conclusion mechanical modeling [26, p. xxii-xxiii]. It is also unclear what the “aid” of Antonio Garbasso was. There are no any references about the cooperation between these two men and participation of Garbasso in logic machine design at all known biographies of that scientist.

PATENT OF CHARLES P. R. MACAULAY

In November 25, 1913 Englishman Charles P. R. Macaulay lived in Chicago was granted a patent number 1079504 on mechanical logic machine (the application was filed in 1910) [21]. Thus, his device became the first patented logical machine.

The machine has the shape of a shallow rectangular case with three horizontal lines of openings in which you can observe the combination of terms of propositions (Fig. 43). The top line displays the consistent combinations of terms and the bottom line displays inconsistent combinations. The middle (special) line of openings is used for temporary storage of consistent propositions. The main part of construction consists of sixteen vertically arranged strips which can freely move when tilting the case. Macaulay called them the *character strips*. Each strip on its upper, middle and lower part has one of the combinations of small and capital letters that represent the terms of propositions – abcd, Abcd, aBcd, ..., ABCD.

In addition, there are eight horizontal strips *h*, which can be independently moved by hand from the extreme left (the first position) to the extreme right position (second position) and back. At the left vertical row you can read the letters presenting the subject and predicate in the proposition. By pressing (i.e. moving from position to position) the strip *h* you can fix the corresponding character strips in appropriate position.

Macaulay pointed out that his machine can be successfully used for solving a variety of tasks, such as in propositional logic, and described in details the decision one of them.

Martin Gardner characterized Macaulay logical machine as the most perfect one of Jevons’ type. Really, in comparison with the machines of Jevons, Marquand and Khrushchev, it is more simple and compact. In principle this machine as it is described in the patent seems appropriate inventor’s declarations. However, there is no evidence that it actually was built. In any case, there is no any reference on the really manufactured patent model in the application. In addition, some of the technical details of the machine design are omitted or not clearly described in this patent. So, it is difficult to say with certainty whether it is possible to realize this project in a really working construction.

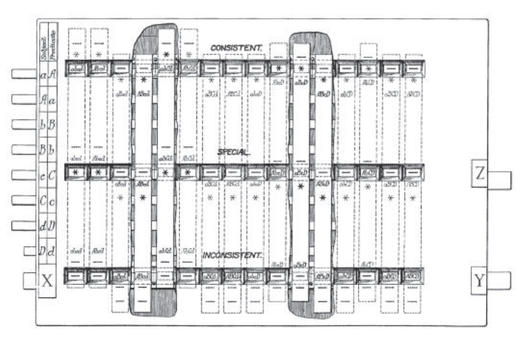


Figure 43. Drawing of Macaulay logical machine.

Any biographical data about Macaulay person is still missing. However, we can say for surely that his work in the field of logic was not only the design of logical machine. This is confirmed by his interesting article *Logic in Numbers* published in *The Monist* (July 1918, vol. 28, No. 3, pp. 472-478), discovered by the authors of this paper.

Electrical Logic Machine of Benjamin Burack

In 1936 young graduate of Lewis Institute in Chicago Benjamin Burack (1914-2001) demonstrated the first in the world electrical logic machine on the annual conference of Institute. Machine was mounted inside the cover of the small case (Fig. 44), with polished wooden blocks, 13.75×6.25×2 cm*,* resting in compartments in the bottom half of the case. It could work from the batteries or from the electrical network. Total weight of the case, including machine and blocks, was approximately 11 kg.

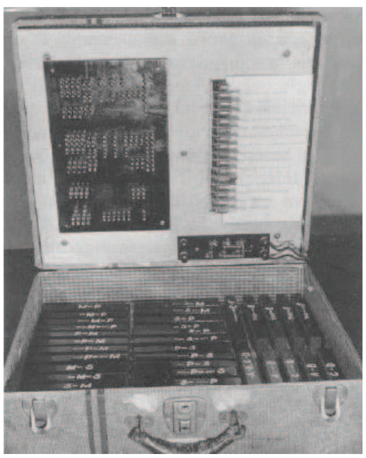


Figure 44. Electrical Logic Machine of Benjamin Burack.

One of the syllogism propositions is printed on the front of each block. For example, if S – subject and P – predicate than there are four blocks representing possible conclusions:

All S is P

No S is P

Some S is P

Some S is not P.

Using M for the middle term, there are eight blocks for all the possible combination with the first premise and eight blocks for the possible combinations with the second premise. Additional blocks provide for testing hypothetical syllogisms, disjunctive syllogisms, conversion, and obversion.

Separate contact areas at selected positions are located on the back of each block. For example, the block representing the proposition "Some M is not S" on its front has the back contacts represent the following items of information:

The middle term M is undistributed,

The proposition is negative,

The proposition is particular (refers to "some").

In order to test the syllogism it is only necessary to select three blocks presenting two premises and conclusion and place them onto three spaces provided on the panel of machine. Metal contacts close the electrical circuits and if the syllogism contains one or more fallacies, one or more light bulbs located on the right side of case cover will light up. Each light bulb is identified by a printed name of fallacy (there is a plate with the name of fallacy close to the bulb). That is, there are seven fallacies for category syllogisms. Three light bulbs signalized about the fallacies in hypothetical syllogism, and three another bulbs are for disjunctive syllogism, conversion and obversion accordingly. There is a separate electrical circuit for each possible fallacy and several light bulbs could switch on simultaneously.

Burack published the description of his machine only in 1949 [11]. Unfortunately, most part of description was devoted… to manufacture technology of the contacts on the wooden blocks. The author mentioned that unlike logic machines of Stanhope, Jevons, Venn, Marquand, Pastore and Macaulay, which indicated the conclusions derivable for given premises, his machine identified the formal fallacies in the syllogisms of various types and tested the correctness of conclusions.

It is worth to add that further Burack became a famous psychologist. His whole career was related with Roosevelt University in Chicago (by the way, he did not work there at the moment of logic machine invention). He was a professor of this University for a long time and the head of the laboratory of experimental psychology (Fig. 45).

Figure 45. Benjamin Burack in classroom, 1957.

He wrote dozens articles on psychology (for example, he made very interesting analysis of lie detector operation) and in 1974 he published the historical novel *Mara*, *Mura*. Logic machine was not his only invention. Burack also created original chromoscope and stereo camera. He regularly used various visual aids of his own design during the lectures and public presentations (one of it we can see on Fig. 46).

At the end of 1969 Burack passed his logic machine to the Smithsonian Museum. Many newspapers mentioned this fact. One of the articles said:

A logic machine has gone to the Smithsonian Institution, the gadget's creator said Sunday.

"I figure that as I get older, I may kick off and someone would find it in my closet and not know what to do with it". Benjamin Burack, a professor of psychology at Roosevelt University said.

He said the machine, which he dreamed up while an undergraduate at Illinois Institute of Technology, accepts premises fed into it by an operator and then tests the validity of a conclusion based on the premises.

If the conclusion is wrong, a light flashes for a wrong answer.

The machine cost $40 and was fun to make, Mr. Burack said, but there wasn't much use for it.

"I did think colleagues might use it, in class especially, but no one seemed interested" (*Logic Device Put To Rest*, Toledo Blade, November 11, 1969).

Figure 46. Benjamin Burack, 1962 (*Chicago Tribune*, December 2, 1962).

This article contains several interesting details. For example, Burack said about the cost of his machine – $40 (in comparison, in 1939-41 electronic computer ABC by John V. Atanasoff and Clifford Berry was built for the $650 worth grant and ENIAC in 1942-45 was built for $400.000). It is also interesting to mention that though it was said in the article [11]: "It has been used successfully in logic classes and evokes sharp student interest", but from the Burack's interview in 1969 it is clear that University administration had no much interest in his machine. Probably that is why "there wasn't much use for it".

THE END OF AN ERA

In 1947 two undergraduates of Harvard University, William Burkhardt and Theodor A. Kalin built a small relay logic machine (Fig. 47). They did not know about the predecessors and were inspired by the theory of Shannon and a desire to make their student's life easier by automating many tasks of mathematical logic. Their machine of only $150 cost might be boldly called the first one which could be used for practical purposes [12, pp. 128-130]. The last "classical" logic machines were built in the same time by the Hungarian cybernetician Tihamér Nemes (1895-1960) (Fig. 48). Unfortunately, his machines did not survive [38, p. 296].

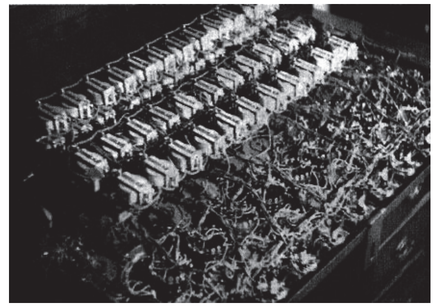


Figure 47. Kalin-Burkhardt Relay Logical Machine.

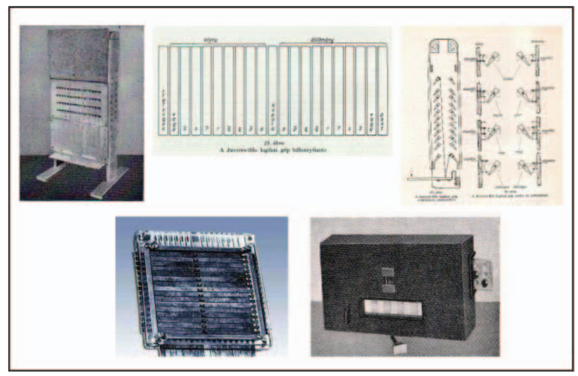


Figure 48. Logic Machines of Tihamér Nemes.

In the last chapter of his monograph Martin Gardner expressed optimism about the fate of logical machines. He suggested that they could be applied in some areas related to the analysis of large arrays of information. However, the events developed in a different way. Although up to the early 1960s in different countries, in England, the USA, the USSR and Czechoslovakia, there were built several specialized relay and electronic logic machines but they of course could not compete with universal electronic computers. From the object of attention of serious scientists logical machines have become the object of student exercises (Fig. 49) and even children's toys ("Brainiac kit" by Edmund C. Berkeley, 1958, see Fig. 50).

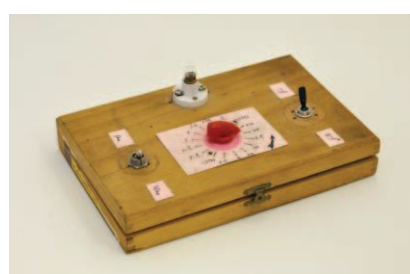


Figure 49. Logical Machine of 1950s.

Figure 50. “Brainiac” advertisement.

In 1949 the English company *Ferranti*, known for its electronic computer Manchester Mark I, built a small electronic logic machine fully functionally equivalent to the mechanical machine of Jevons. At the exhibition devoted to Jevons at Manchester University in 1952 these machines were exhibited side by side. We may see on Fig. 51 a unique photo – the son of the great scientist Herbert Stanley Jevons switches toggle on the electronic version of the machine under the watchful eye of his father, whose marble bust is installed nearby... Today it seems that the photographer illustrated so well a link of times simultaneously unwittingly predicted the end of the centuries-old era of logical machines.

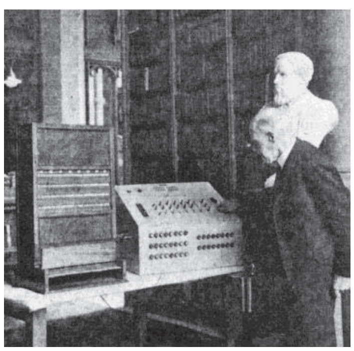


Figure 51. Herbert Stanley Jevons and Logical Machines (*Manchester Guardian*, October 15, 1952).

CONCLUSION

The centuries-old development of logical machines is very interesting page of both computer technology and logic history. In fact, logical machines cannot be called the ancestors of modern computers but our analysis allows us to state for surely that these devices were the very first predecessors of contemporary intellectual informational technologies.

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