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Autor	Thiago Ferreira Lion
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THE COMMODITY AND THE COMPUTER

On the Relation Between the Abstraction of Labor and the Genesis of Computing Science

Thiago Ferreira Lion*

ABSTRACT

In this work we analyze the genesis of computing, which took place between 1830 and the end of World War II, when the first universal computers were actually built. For this, we refer to several key texts by the founders of computer science (Babbage, Lovelace, Boole, Hollerith, Turing and Shannon) analyzing their relationship with the development of commodity and capital, mainly from the theory of Marx and his successors, such as Sohn-Rethel and Adorno. The different notes present aspects in which computing and market development intertwine, in a process in which social reality becomes increasingly mathematized.

*Doutor em Filosofia pela Universidade Federal de São Paulo com estágio doutoral na *Freie Universität Berlin*, atualmente lecionando na *Technische Universität Berlin*. Contato: thiagoflion@hotmail.com

KEYWORDS

Computer Science, Commodity Form, Abstraction of Labor, Marx, Babbage.

A MERCADORIA E O COMPUTADOR

sobre a relação entre a abstração do trabalho e a gênese da ciência da computação

RESUMO

Nesse trabalho analisamos a gênese da computação, ocorrida entre 1830 e o final da segunda guerra mundial, quando os primeiros computadores universais foram de fato construídos. Para tanto nos referimos a diversos textos-chave dos fundadores da ciência da computação (Babbage, Lovelace, Boole, Hollerith, Turing e Shannon) analisando sua relação com o desenvolvimento da mercadoria e do capital, principalmente a partir da teoria de Marx e de seus sucessores, como Sohn-Rethel e Adorno. As diferentes notas apresentam diferentes aspectos em que a computação e o desenvolvimento mercantil se entrelaçam, num processo em que a realidade social se torna cada vez mais matematizada.

PALAVRAS-CHAVE

Ciência da computação, forma mercadoria, abstração do trabalho, Marx, Babbage.

The digital appears as a form of mediation for many of the relationships that previously occurred in an analogical way. Like the commodity exchange, which begins as an occasional exchange of some products in contact between different societies to later place production in general under its form, the digital now seems to gradually impose its universality as a *form* on all segments of social life. Our affective relationships (Lion, 2017), work and education are now mediated by it. Even money and commercial transactions are registered as data in computerized systems, as well as the reading and production of texts, songs, images, etc. The new form based on the production of hardware and software has become universal and now encompasses the very reproduction of the material world.

The aim of this paper is to analyze the historical moment before this generalization, which, however, gave rise to it, relating the development of capitalism (and, therefore, the abstraction of labor that is characteristic of it) with the beginning of computing. It will be done by means of successive notes dealing with different aspects of the early historical relation between capitalism and digitalization, as following: the idea of digital computers as linked to the abstraction of labor; the idea of a universal computer as influencing, through Babbage, the analysis of Marx in *Capital*; how capital can be conceived as an universal mechanism processing reality in a mathematical way (reducing *quality* to *quantity*), in terms that are analogous to a universal computer; how the development of the binary code can be seen as analogous, in mathematics, to the simplifying abstraction of labor, in industrial production, and; the construction of the first computers as depending on the market development and on the State. The successive notes departing from different but connected aspects, gives us a more general picture of the process that was fragmented in itself.[1] The argument will rely mainly on the theoretical framework stablished by Marx and further developed by critical theory, as well as important technical texts written by the founders of computing science. A closer analysis shows that there are points where the two different traditions are, especially in the beginning of computing, interlaced.

As critical philosophy has endeavored to demonstrate that God[2] and capital[3] are analogous human products,[4] it should also be made clear that the existence and functioning of computers are products of human action. Historically it may be obvious, but otherwise not, and the new generations do not know the world before the digital. As in the value of the commodity,[5] in computational technology the finished form, the form in which humans confront it, does not make it clear that it is a product of social relations, and, especially, it does not make it clear *how* it

1 Here we remember Adorno's warning: "The customary objection that the essay is fragmentary and contingent itself postulates that totality is given (…) and acts as though one were in possession of the whole" (Adorno 1991: 9).

2 "The consciousness of God is the self-consciousness of man; the knowledge of God is the self-knowledge of man. Man's notion of himself is his notion of God, just as his notion of God is his notion of himself – the two are identical" (Feuerbach 2012: 37).

3 "Capitalism can be seen as religion, i.e. capitalism essentially serves to satisfy the same worries, torments, and unrest to which the so-called religions once answered" (Benjamin 1991: 100, our translation).

4 "It is nothing but the definite social relation between men themselves which assumes here, for them, the fantastic form of a relation between things. In order, therefore, to find an analogy we must take flight into the misty realm of religion. There the products of the human brain appear as autonomous figures endowed with a life of their own, which enter into relations both with each other and with the human race. So it is in the world of commodities with the products of men's hands. I call this the fetishism which attaches itself to the products of labour as soon as they are produced as commodities, and is therefore inseparable from the production of commodities" (Marx 1976: 165).

5 "Value, therefore, does not have its description branded on its forehead; it rather transforms every product of labour into a social hieroglyphic" (Marx 1976: 167).

can be generated by these relations. The individual finds it ready-made as an existing thing. It is hard to perceive it as a product of social relations, because it does not have the evanescent form of a relation anymore, but the solid form of a thing.

When using a contemporary computer, the intuitive interface does not show that it is a matter of processing mathematical operations, and in fact we don't even have access to all numerical calculations performed in the inside, as Von Neumann anticipated (1945: 1) while designing one of the first valve computers, the EDVAC:

> the device will in general produce essentially more numerical material (in order to reach the results) than the (final) results mentioned. Thus only a fraction of its numerical output will have to be recorded as indicated in 1.2, the remainder will only circulate in the interior of the device, and never be recorded for human sensing.

Even less clear is *how* the human work accumulated over generations could generate such a complex machine. The most experienced programmer cannot know all the calculations happening in the successive layers of programming down to the hardware.[6] On the contrary, each specialist programs in their specific area according to the division of labor, in which they find the previous work accumulated as something given. Thus, the current development work in computing appears as emi-

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6 "The program that hides the truth about the hardware from the programmer and presents a nice, simple view of named files that can be read and written is, of course, the operating system [...] the function of the operating system is to present the user with the equivalent of an extended machine or virtual machine that is easier to program than the underlying hardware" (Tanenbaum 2001: 4).

nently technical, as dealing with a specific objectivity of the thing that barely resembles its *human* origin.

The Idea of the Universal Computer as Departing from the Human

Through reading the founders of computing, however, we find another perspective, from the time when this was just an idea waiting for its future realization. In this stage it was clear how the very conception of the first computers started as an abstraction of human labor that it aimed to automatize, as Turing wrote (1950: 436) in his famous article *Computing Machinery and Intelligence*:

> The idea behind digital computers may be explained by saying that these machines are intended to carry out any operations which could be done by a human computer. The human computer is supposed to be following fixed rules; he has no authority to deviate from them in any detail. We may suppose that these rules are supplied in a book, which is altered whenever he is put on to a new job.

A "human computer" was a profession, its members being hired to perform calculations for different purposes before the development of digital computers. Since the renaissance astronomers would hire a "computer" to assist them in the mechanical process of calculating, field that, from the late 19th century onwards, became increasingly dominated by women. It is human task, in this case relying in the ability of make calculations, that is being automated in a similar way to which an industrial loom has automated the manual weaving process. Here we can already see the relationship between the capitalist abstraction of labor, which increasingly prescribes a regulated routine, and the design of a machine developed to automate this process. A practical human act is first broken into different steps, to then be replaced as prescribed steps followed by a machine. Whilst the automatic loom machine seeks to replace a determined material action, the movement of fabric production, the computer proceeds with a "symbolic" action, a calculation whose result is not in its material expression, but as a mathematical operation.

When we go further back into the history of computers and analyze the progression of the inventions of Charles Babbage – who for the first-time conceived computers – we notice another fundamental difference between these and other machines, which is linked to the universality of this human action that it automatizes. Far from substituting a given calculation or sequence of calculations, a universal computer can, by its programming detached from the material structure of the machine, proceed with any sequence of calculations. Therefore, it constitutes a *universal machine*, that is, one that is not limited to a specific function, but receive from the outside the instructions on *how* to perform a task. This universality also means that, let aside questions about speed and memory, a universal computer is equivalent in its functionality to any other universal computer,[7] something completely different from all tools and previously existing machinery. I intend to present in this paper that the abstraction of labor, as a fundamental part of the productive rationalization process, has a decisive role in the conception and subsequent production of universal computers.

The difference between the two machines that Babbage conceived illustrates logically and historically the beginning of this development. First, the inventor built the *Difference Engine*, which calculated data that was previously handcrafted for the Board of Longitude's new lunar tablets. The machine performed a specific set of operations.[8] It is interesting to point out that the importance of the calculation tables lies in enabling the possibility to know the *longitude*, facilitating the long-distance navigation required by the flourishing European capital. Later on, Babbage was able to describe in detail the functioning of the first universal computer, the Analytical Engine, "a machine of the

7 "This special property of digital computers, that they can mimic any discrete state machine, is described by saying that they are universal machines. The existence of machines with this property has the important consequence that, considerations of speed apart, it is unnecessary to design various new machines to do various computing processes. They can all be done with one digital computer, suitably programmed for each case. It will be seen that as a consequence of this all digital computers are in a sense equivalent" (Turing 1950: 441-442).

8 "The Difference Engine is the embodying of one particular and very limited set of operations, which (see the notation used in Note B) may be expressed thus (+, +, +, +, +, +), or thus, 6(+). Six repetitions of the one operation, +, is, in fact, the whole sum and object of that engine. It has seven columns, and a number on any column can add itself to a number on the next column to its right-hand. So that, beginning with the column furthest to the left, six additions can be effected, and the result appears on the seventh column, which is the last on the right-hand. The operating mechanism of this engine acts in as separate and independent a manner as that of the Analytical Engine; but being susceptible of only one unvarying and restricted combination, it has little force or interest in illustration of the distinct nature of the science of operations" (Lovelace 1842).

most general nature" that can be used to carry out any type of calculation.[9]

The idea was that the programming, which instructs *how* to compute data, should be separated from the structure of the machine by means of cards on which it would be entered. Ada Lovelace, in charge of developing an algorithm for the machine, stated that "the bounds of arithmetic were [...] outstepped the moment the idea of applying the cards had occurred" (Lovelace 1842). Such cards were designed based on the loom control system developed by Jacquard in 1804, allowing its instruction set to be given separately from the number to be processed,[10] or, in other words, the data input for the operation is different from the set of rules that prescribes *how* to process the operation. One can see here again the connection between the first important product of industrial revolution, textiles, and the abstract idea of a universal computer.

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9 "The Analytical Engine is an embodying of the science of operations, constructed with peculiar reference to abstract number as the subject of those operations. The Difference Engine is the embodying of one particular and very limited set of operations" (Lovelace, 1842).

10 "These cards, however, have nothing to do with the regulation of the particular numerical data. They merely determine the operations to be effected, which operations may of course be performed on an infinite variety of particular numerical values, and do not bring out any definite numerical results unless the numerical data of the problem have been impressed on the requisite portions of the train of mechanism (...) the particular numerical data and the numerical results are determined by means and by portions of the mechanism which act quite independently of those that regulate the operations. In studying the action of the Analytical Engine, we find that the peculiar and independent nature of the considerations which in all mathematical analysis belong to operations, as distinguished from the objects operated upon and from the results of the operations performed upon those objects, is very strikingly defined and separated" (Lovelace, 1842).

The way of processing data is given not by the structure of the machine itself, but by a program inscribed on the card that will say *how* the machine will act on the number to be calculated.[11] In this way, the machine also had a "library" consolidated in cards, a resource that is still widely used in current systems. In her notes attached to the translation of S*ketch of The Analytical Engine Invented by Charles Babbage*, Lovelace gives us a sense of her advanced thinking that may reach further than that of Babbage himself, when she develops the implications of computing as a *new form of language*, as well as the intimate philosophical relationship it establishes between the mental and material world (Lovelace 1842):

> The Analytical Engine does not occupy common ground with mere "calculating machines". It holds a position wholly its own; and the considerations it suggests are most interesting in their nature. In enabling mechanism to combine together general symbols in successions of unlimited variety and extent, a uniting link is established between the operations of matter and the abstract mental processes of the most abstract branch of mathematical science. A new, a vast, and a powerful language is developed for the future use of analysis, in which to wield its truths so that these may become of more speed and accurate practical application for the purposes of mankind than the means hitherto in our possession

11 "He would lash cards together end to end and punch holes in them that could be 'read' by a number of movable pins in the machine. The holes would 'encode' as we would now say, information about which operations to employ over which symbols. Given a sophisticated enough control system for the cards, one would be able to repeat the same set of cards an indeterminate number of times (now called 'looping', but he called it 'backing' the cards), and one would be able to decide which cards to execute on the basis of intermediate results obtained during the computational process (now known as 'conditional branching'). Both processes are central to modern computing theory". (Green 2005: 38).

> have rendered possible. Thus not only the mental and the material, but the theoretical and the practical in the mathematical world, are brought into more intimate and effective connexion with each other. We are not aware of its being on record that anything partaking in the nature of what is so well designated the Analytical Engine has been hitherto proposed, or even thought of, as a practical possibility, any more than the idea of a thinking or of a reasoning machine.

Lovelace even goes so far as to say that "indeed we may consider the engine as the material and mechanical representative of analysis" or, as she also puts it, "an embodying of the science of operations" (Ibid). The relationship subjected to the philosophical critique of ideology, above all, between thought/matter and abstraction/concreteness here presents itself in a new dimension. It is an abstraction developed by human thought that can then take shape in the form of a machine capable of processing all types of analysis, as long as it is given according to mathematical parameters.

The fact that it was possible to conceive such a universal machine in a purely mechanical way helps us to get rid of the superstition that its functioning is somehow related to electricity in a way analogous to our neurons, as Turing already pointed out in 1950.[12] In this sense, the mechanical execution of an algo-

12 "The idea of a digital computer is an old one. Charles Babbage, Lucasian Professor of Mathematics at Cambridge from 1828 to 1839, planned such a machine, called the Analytical Engine, but it was never completed. Although Babbage had all the essential ideas, his machine was not at that time such a very attractive prospect. The speed which would have been available would be definitely faster than a human computer but something like 100 times slower than the Manchester machine, itself one of the slower of the modem machines. The storage was to be purely mechanical, using wheels and cards. The fact that Babbage's Analytical Engine was to be entirely mechanical will

rithm, of a dead chain of tasks, also cannot be the basis for the utopia that reduces human knowledge to an algorithm.[13] The problem of an effective universality, this time embodied in the machine, is thus first *conceived* in this new form of a universal computer, although Babbage until his death in 1871 was not able to construct it. The genius of his conception is clear when we compare the understanding of what a universal machine would be with the limitations of the epoch. Another genius like Charles Sanders Peirce, even half a century after Babbage, shows that was not easy to reach the understanding of a universal machine when he stated that "the capacity of a machine has absolute limitations; it has been contrived to do a certain thing and it can do nothing else".[14]

help us to rid ourselves of a superstition. Importance is often attached to the fact that modem digital computers are electrical, and that the nervous system also is electrical. Since Babbage's machine was not electrical, and since all digital computers are in a sense equivalent, we see that this use of electricity cannot be of theoretical importance" (Turing 1950: 439).

13 "The limits of the algorithm are analogous to those of logic: The logic presupposes subsumptive and already known answers; if contradicting answers arise, it is over [...] Sometimes one comes across the utopian dream that all human knowledge can be 'algorithmized' and stored in a computer, which would then accelerate knowledge that put all previous scientific revolutions in the shade. This idea fails because human knowledge is organized into discourses and discourses have no 'premises'" (Jäger 1985: 121-122, our translation).

14 Idea that Peirce repeats when he says that "the machine (...) would only do the special kind of thing it had been calculated to do". It is interesting to note that, even having mentioned Babbage in his text, Peirce does not seem to realize that the possible solution that he himself imagined for the development of a future machine is the same that Babbage had already developed more than 50 years before, with references in Jacquard's card system: "I do not think there would be any great difficulty in constructing a machine which should work the logic of relations with a large number of terms. But owing to the great variety of ways in which the premises can be combined to produce different conclusions in that branch of logic, the machine, in its first state of development, would be no more mechanical than a hand-loom for weaving in many

The Idea of a Universal Computer as Prior to the Analysis of Capital: Marx Reader of Babbage.

Babbage more than anything else considered himself to be a most general thinker, a philosopher, as the name of his 1864 autobiography *Passages from the Life of a Philosopher* (Babbage 1864) illustrates. Before building the *Difference Engine* he had already become well-known at a very young age as he led a mathematical revolution in Cambridge aimed at replacing the Newtonian notation system with the more easily manipulated Leibnizian notation system (Green 2005: 36). In 1832 he published his influential book *On the Economy of Machinery and Manufactures* in which he explored, from the analysis of the functioning of several factories, the effects of the division of labor in production, and how this division, simplifying (i.e. making it more abstract) the work carried out individually, impels the development of tools and machinery:

> The division of labour suggests the contrivance of tools and machinery to execute its processes. When each process, by which any article is produced, is the sole occupation of one individual, his whole attention being devoted to a very limited and simple operation, any improvement in the form of his tools, or in the mode of using them, is much more likely to occur to his mind, than if it were distracted by a greater variety of circumstances. (Babbage 2009: 135)

colors with many shuttles. The study of how to pass from such a machine as that to one corresponding to Jacquard loom, would be likely to do very much for the improvement of logic" (Peirce 1887: 170).

Here again, human action is seen as *labor*, as a kind of routine imposed by capital that tends to simplify, to reorganize itself based on a higher technological domain compelled by the economic imperative of expanding production.[15] One can see how the capitalistic *division* of work is, at the same time, abstraction of *work* or, in other words, labor. This simplification or abstraction process is the breaking of reality in small pieces that can be reordered, as Horkheimer and Adorno pointed out (2002: 210) "the whole ingenious machinery of modern industrial society is no more than nature dismembering itself". Babbage relates this simplification of work with the production of machines saying that "when each process has been reduced to the use of some simple tool, the union of all these tools, acted by one moving power, constitutes a machine" (Babbage 2009: 136).

This passage above was quoted by Marx (1990: 153) in his critique of Proudhon in *The Misery of Philosophy.* Marx also quotes Babbage many times in the first volume of *Capital* (Marx 1976: 466, 469, 470, 497, 514, 528 and 529) especially when dealing with the division of labor and machines. Babbage drew his ideas from the analysis of the division of labor on the effective development of different industries and considered that "workshops (...) contain within them a rich mine of knowledge, too

15 "The despotism exercised by capital over labour within the capitalist production process is, by contrast, an essential factor of its continuous rational reorganization, which in turn constitutes the condition of entry for technology –in the sense of a systematic application of scientific knowledge on production processes –into the development of capitalist production as reproduction of, i.e. accumulation of, capital. Therefore two dimensions which had remained separate in earlier societies, are continuously merged within societies dominated by the capitalistic mode of production: The control exercised by capital over the production process and the (re)organisation of this production process itself" (Wolf 2009: 6).

generally neglected by the wealthier classes" (Babbage 2009: 6). The process of labor abstraction, its simplification that enables automatization, was the source of Babbage's idea of a universal computer. Here one can see how the division of labor, elevated to a whole new level by capitalistic production, is the source not only for material products, but also of abstract computing science:

> The applied sciences derive their facts from experiment; but the reasonings, on which their chief utility depends, come more properly within the province of what is called abstract Science. It has been shown that the division of labour is no less applicable to mental productions than to those in which material bodies are concerned (Babbage 2009: 307).

With the application of this principle of division of labor to mental productions, this abstract science would evolve and, as Babbage said, it "may be found that the dominion of mind over the material world advances with an ever-accelerating force" (Babbage 2009: 318). In our times when the digital has coated relationships and reality itself with its form, one cannot help but admire that such a prediction could have been made 190 years ago.

The influence of Babbage on other writings by Marx has been recently pointed out,[16] and in particular in the now famous "fragment about machines", in which Marx foresees what would be a coming collapse of capitalist production by the development of the *general intellect,* i.e., science and technology, making labor obsolete as a measure of value.

It is interesting to note that Babbage's book, which influenced Marx in his analysis of machines in *Capital*, was conceived taking into account the idea of building the first computers. In *On the Economy of Machinery and Manufactures* Babbage writes that the book "may be considered as one of the consequences that have taken from the Calculating-Engine, the construction of which I have been so long superintending" (Babbage 2009: 3). Not only does the idea of a computer derive from capitalist production that establishes a radical form of division of labor, as seen in the inspiration that Babbage sought in factories to think about it, but also inversely: the analysis of capital by Marx literally has, as one of its written sources, a book influenced by the idea of a universal computer.

16 "Scholars have wondered where the expression 'general intellect' came from, as it appears only once, in English, in the *Grundrisse.* Virno thought he detected the echo of Aristotle's *nous poietikos* and Rousseau's *volonté générale.* As the 'Fragment on Machines' follows strains of argumentation that are similar to chapters 14 and 15 of Capital on the division of labour and machinery, it is not surprising that the missing sources can be found in the footnotes to these chapters of Capital. These common strains of argumentation are, fundamentally, Babbage's theory of machinery, and it is by following Marx's reading of Babbage in chapter 14 of Capital that the notion of general intellect can be reliably traced back to William Thompson's notion of 'knowledge labour'" (Pasquinelli 2019).

Capital as a Universal Mechanism Analogous to the Computer

The very characterization of Capital by Marx as an "automatic subject" (Marx 1976: 255) points to a social mechanism with a blind moving power. A mechanism which acts as a *subject*, in the sense that it takes the decisions, but also that is *automatic*, a predetermined movement devoid of choice. Once in place it needs to grow, to expand itself colonizing deeper and deeper layers of the social and the natural world. Capitalism reduces all the differences of reality to its form. Different things like minerals, fish, earth and labor have their properties reduced to a measure of value, *how much* money they represent. At the same time the money used to make more money, the definition of capital, relies on this changing form as a medium to expand itself. At one-time capital is only a *given* sum of money, at another it is a commodity, and by changing between these forms it expands itself moving a social mechanism constituted from human action and which is capable of *processing* reality. All the real differences are abstracted and understood as numbers, representing the *amount* of money. Capital is a social relationship that moves and that all encompasses, but that in itself is devoid of life, as Marx puts it:

> In truth, however, value is here the subject* of a process in which, while constantly assuming the form in turn of money and commodities, it changes its own magnitude, throws off surplus-value from itself considered as original value, and thus valorizes itself independently. For the movement in the course of which it adds surplus-value is its own movement, its valorization is therefore self-valorization [*Selbstverwertung*]. By virtue of being

> value, it has acquired the occult ability to add value to itself (...) In simple circulation, the value. of commodities attained at the most a form independent of their use-values, i.e. the form of money. But now, in the circulation M-C-M, value suddenly presents itself as a self-moving substance which passes through a process of its own, and for which commodities and money are both mere forms (Marx 1976: 255-256).

Capital is already, according to Marx's description, a kind of social mechanism that processes all reality and equalizes every sensible difference as a commodity possessing greater, lesser or equal value. This process of capital is, at the same time, the process of abstraction of labor. It is increasingly reduced to simple tasks, which can be performed over and over again without requiring any special skills. The work that used to be artisanal and carried traces of its performer, now becomes more and more abstract, more indifferent to the personal characteristics of those who produce. The labor from different workers are qualitatively the same and thus differ only in quantity, in terms of greater or lesser duration of work, which is then to be measured numerically. Capital reduces through the abstraction of labor all qualitative differences to a difference in quantity and induces a kind of quantitative, numerical consideration of reality, processing the world through its abstract metabolism:

> It is true that the value of money varies, whether as a result of a variation in its own value, or of a change in the values of commodities. But this on the one hand does not prevent 200 ounces of gold from continuing to contain more value than 100 ounces, nor on the other hand does it prevent the metallic natural form of this object from continuing to be the universal equivalent

> form of all other commodities, and the directly social incarnation of all human labour. The hoarding drive is boundless in its nature. Qualitatively or formally considered, money is independent of all limits, that is it is the universal representative of material wealth because it is directly convertible into any other commodity. But at the same time every actual sum of money is limited in amount, and therefore has only a limited efficacy as a means of purchase. This contradiction between the quantitative limitation and the qualitative lack of limitation of money keeps driving the hoarder back to his Sisyphean task of accumulation. He is in the same situation as a world conqueror, who discovers a new boundary with each country he annexes (Marx 1976: 230-231).

A parallel can be drawn between capital as a social form that processes any *material quality* by reducing it to a commodity which has a given *quantity of value*, and the computer as a universal machine, which, operating with *quantities*, reproduces in its form sensitive *qualities*, such as an image or a sound. Both are human acting placed in a mechanical way, as following a pre-determined rulebook. It may be difficult to represent social relations as something mechanic, but before Marx Hegel already considered that the notion of mechanism encompasses not only the external functioning of mechanical objects, but also the "external" behavior of humans, when, by virtue of some ceremonial or social convention, a certain form of action is automatically reproduced.[17]

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17 "Just as pressure and shock are mechanical relationships, we also know mechanically, by heart, insofar as the words have no meaning for us and remain external to the meaning, imagining, and thinking; they are also external to themselves, a meaningless sequence. Action, piety, etc., is just as mechanical, in so far as to man through ceremonial laws, advice of conscience, etc., we determine what he is doing, and his own self is thus external" (Hegel 1983: 352-353, our translation).

Humankind unconsciously mathematized its social relations and perception of nature through commodity exchange before being able to conceive and construct a computer. As Horkheimer and Adorno (2002: 19) put it "nature itself is idealized on the model of the new mathematics. In modern terms, it becomes a mathematical manifold. Thought is reified as an autonomous, automatic process, applying the machine it has itself produced, so that it can finally be replaced by the machine". From our perspective here, it was possible to conceive a universal computer only because social reality in itself was already mathematized in the form of a social mechanism. From this point of view, both capital (with its blind and repetitive drive for the valorization of value) and the computer (with its algorithms) can be said to be universal mechanisms, products of the abstraction of production relations marked by the exploitation of wage labor, i.e., *quantified labor.*

Linking the Development of Binary Code to that of Commodity-Form

It is possible to apprehend the relationship between computation and capital also departing from the relation of circulation to the form of knowledge. In this sense the analysis of the connection between the commodity form and mathematics by Alfred Sohn-Rethel seems to be fruitful:

> The comparatives of 'more' and 'less' used in a deal of exchange do not imply a quantitative comparison between, say, tons of coal and reams of paper, or of acres of land and yards of linen. The interrelational

> equation posited by an act of exchange leaves all dimensional measurements behind and establishes a sphere of nondimensional quantity. This is the pure or abstract quality of cardinal numbers, with nothing to define it but the relation of greater than (>) or smaller than (<) or equal to (=) some other quantity as such. In other words, the postulate of the exchange equation abstracts quantity in a manner which constitutes the foundation of free mathematical reasoning (Sohn-Rethel 1978: 47).

This argument is, on the side of commercial circulation, the equivalent to the abstraction of labor on the side of production, both constitutes two faces of the same coin: the capitalistic reproduction where the commodity form became all dominant. In this sense one could not only analyze the development of computers as machinery as a sort of unfolding of the form of capitalist social relations, but also analyze the development of the mathematics that made it possible to operate machines. Babbage's Analytical Engine, although it could not be realized in the epoch due to the technological difficulties for the manufacture of mechanical parts, also had very evident mathematical limitations when compared to the first universal computers created in the 20th century. The most important of these concerns the use of decimal code to conduct operations, our daily used mathematical base with numbers from 0 to 9, in the absence of the development of the binary code, with numbers 0 and 1.

The one who seems to have been the first to clearly point out the importance of binary code was Leibniz, who as early as 1703 introduced his idea in a short article, anticipating its enormous future importance:

> The computation by two, that is to say by 0 & 1, in reward of its length, is the most fundamental for science, and gives new discoveries, which are then useful, even for the practice of numbers, especially for geometry; of which the reason is, that the numbers being reduced to the simplest principles, like 0 & 1, it makes appears by all sides a marvelous order (Leibniz 1703: 87, our translation).

What Leibniz saw in binary code in relation to mathematics can be considered analogous to what Babbage saw in mechanical work simplified by the manufacturing division of labor. In both cases, it is a question of reducing to simpler, more abstract principles, which allow for a clearer and thus more automatable order. It is as if the mathematical system had been reduced to its simplest elements that express only *identity* and *difference*, *yes* or *no*. Leibniz also realized that this binary form thus allowed to express all other whole numbers, because as he says presenting a table "We see here at a glance the reason for a famous property of double geometric progression in whole numbers (integers), which means that if we only have one of these numbers of each degree, we can include all the other whole numbers below the double of the highest degree" (Leibniz, 1703: 85-86). However, it is only with the formulation of Boolean logic in 1848 that it became consolidate the understanding that 0 and 1 can, as long as they are recombined, express any elective symbols. Boole summarizes it at the end of his *The Mathematical Analysis of Logic*:

> In virtue of the principle, that a Proposition is either true or false, every elective symbol employed in the expression of hypotheticals admits only of the values 0 and 1,

> which are the only quantitative forms of an elective symbol. It is in fact possible, setting out from the theory of Probabilities (which is purely quantitative), to arrive at a system of methods and processes for the treatment of hypotheticals exactly similar to those which have been given. The two systems of elective symbols and of quantity osculate, if I may use the expression, in the points 0 and 1. It seems to me to be implied by this, that unconditional truth (categoricals) and probable truth meet together in the constitution of contingent truth (hypotheticals). The general doctrine of elective symbols and all the more characteristic applications are quite independent of any quantitative origin (Boole 1948: 82).

Thus, we have the simplest possible system in which, through quantitative means, qualities can be expressed.[18] It is the basis for today's possibility, through an immense chain of 0 and 1, for example, to reproduce a film with its qualitative differences in sounds and images. The idea of using Boolean logic to operate the first effectively existing universal computers, however, had to wait until the fourth decade of the 20th century to became reality.[19]

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18 Lovelace already understood this possibility of expressing qualities through mathematics, despite still conceiving things in a decimal system: "Many persons who are not conversant with mathematical studies, imagine that because the business of the engine is to give its results in numerical notation, the nature of its processes must consequently be arithmetical and numerical, rather than algebraical and analytical. This is an error. The engine can arrange and combine its numerical quantities exactly as if they were letters or any other general symbols" (Lovelace 1842).

19 Babbage, however, already seemed to see the need to precisely refine the mathematical methods of analysis, dealing with the machine that would calculate the navigation tables, says that: "when the completion of a calculating-engine shall have produced a substitute for the whole of the third section of computers, the attention of analysts will naturally be directed to simplifying its application, by a new discussion of the methods of converting analytical formulae into numbers" (Babbage 2009: 156).

The Construction of the First Universal Computers Depending on the State and Market Development as Conclusion to these *Notes*

Even though both the idea of a universal computer and the mathematics necessary for its operationalization were already conceived, a general development of production was still waiting so computers could be actually constructed. This development cannot be understood as a mere development of parts and components, or even just as its technical standardization, but also as the creation of the economic demand for this type of machinery. Here, on the one hand, a certain independence of science from economics is revealed, since the general idea of a universal computer could be developed almost a century before it was manufactured. On the other hand, the ultimate dependence on economic factors is shown, as it was first necessary to create a commercial demand for non-universal computers to gradually develop not only the production of components, but also the need for such machines.

This development took place in the most dynamic economy of the time, the US economy, and faced with a very defined problem: the difficulty of conducting and compiling data from the census of 1890 in a context of rapid population growth. In 1889 there were still uncompiled data from the 1880 census and it was feared that the same would happen with the data collected in 1890, with its tabulation not being completed in the ten years until the next census (Rex 1961: 11). Herman Hollerith, who had been working on a solution to the problem since the beginning of the decade, in 1887 used successfully one of his machines to tabulate mortality statistics for the city of Baltimore.[20] After that, he won with his machine[21] a competition to find solutions that would facilitate the census, generating the expectation of saving around two hundred and fifty thousand days/person of work.[22] This machine worked with punched cards in a decimal system and compiled the data specifically aimed at the census and so, although it was later improved developing itself more and more beyond its specific functions, it did not constitute a universal computer.[23] With his success Hollerith founded the Computing-Tabulating-Recording Company, later in 1924 renamed International Business Machines Corporation (IBM). This company was central to the development of computers, both in terms of technology and in the proprietary way that the development of *general intellect* took place under the US patent regime.

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20 "The City of Baltimore used Hollerith Machines in 1887 to tabulate mortality statistics. This was· the first use of punched-card accounting" (Rex 1961: 11).

21 US patent No. 395,782 of Jan. 8, 1889.

22 "Four districts from the city of St. Louis were chosen, using the data which had been collected in 1880 Projecting these figures for the total census gave the Hollerith System an advantage of almost one-quarter million man days, or $600,000 if figured in money" (Rex 1961: 12).

23 "Hollerith's contributions to modern computing are… incalculable": He did not stop at his original 1890 tabulating machine and sorter, but produced many other innovative new models. He also invented the first automatic card-feed mechanism, the first key punch, and took what was perhaps the first step towards programming by introducing a wiring panel in his 1906 Type I Tabulator, allowing it to do different jobs without having to be rebuilt! (The 1890 Tabulator was hardwired to operate only on 1890 Census cards.) These inventions were the foundation of the modern information processing industry" (Columbia University 2001).

The development of the non-universal computer industry together with the demands arising from the world wars, especially the second, formed the generation of scientists who finally was able to build the first universal computers. Names such as Alan Turing, Claude Shannon and John von Neumann, sharing each other's developments in what was mainly state-funded research, were fundamental in making computing a reality. Shannon, in addition to being considered the father of information science by describing in detail the treatment of noise in 1948 (Shannon 1948: 379-423) (where, for example, the term *bit* is used for the first time) had previously, in 1938, written what is considered by many to be the most influential master's work in computing science history. He shows how to construct the circuits themselves in binary logic, by reducing the other many possibilities of circuit building to the minimum, in order to express 0 or 1:

> We shall limit our treatment of circuits containing only relay contacts and switches, and therefore at any given time the circuit between any two terminals must be either open (infinite impedance) or closed (zero impedance) (Shannon 1938: 472).

It describes in a simple way a complete treatment of how to carry out in the material reality of the circuits the Boolean symbolic logic,[24] which must thus be constructed reflecting the binary logic through parallel circuits (Shannon 1938: 471):

> The method of attack on these problems may be described briefly as follows: any circuit is represented by a set of equations, the terms of the equations corresponding to the various relays and switches in the circuit. A calculus is developed for manipulating these equations by simple mathematical processes, most of which are similar to ordinary algebraic algorisms. This calculus is shown to be exactly analogous to the calculus of propositions used in the symbolic study of logic. For the synthesis problem the desired characteristics are first written as a system of equations, and the equations are then manipulated into the form representing the simplest circuit. The circuit may then be immediately drawn from the equations. By this method it is always possible to find the simplest circuit containing only series and parallel connections, and in some cases the simplest circuit containing any type of connection.

In 1937 Turing had published his first famous article stating that "it is possible to invent a single machine which can be used to compute any computable sequence" (Turing 1937: 241) in which he described the functioning of a universal computer. These ideas formulate the effective bridge between abstract

24 "The algebra of logic, originated by George Boole, is a symbolic method of investigating logical relationships. The symbols of Boolean algebra admit of two logical interpretations. If interpreted in terms of classes, the variables are not limited to the two possible values 0 and 1. This interpretation is known as the algebra of classes. If, however, the terms are taken to represent propositions, we have the calculus of propositions in which variables are limited to the values 0 and I" (Shannon 1938: 474).

mathematics and the real world, as already anticipated a century before by Lovelace.

Here one can also see the importance of the state investment and the war effort in the constructing of the computers. In 1943 the team Turing worked for produced the first *Colossus*, a valve computer programmable by switches and plugs (not by a program in memory) to break the *Enigma* machine cryptography used by the Nazis. In 1945 in the United States, the ENIAC was put into operation – to calculate ballistic trajectories and technical aspects of the hydrogen bomb – which operated in the decimal system and was programmable by switches. In the same year John Von Neumann wrote his *First Draft of a Report on the EDVAC*, about a new computer which would consist of a universal computer like the ENIAC, but with internal memory and operating binary system.[25] This writing constituted the paradigm of computer architecture, defining the machine's components general relation until today.

With the construction of the EDVAC (*Electronic Discrete Variable Automatic Computer*) in 1949 the World had the first universal binary computer operating with a stored-program. This conclusion, therefore, far from being a summarized repetition of the analysis expressed in this work, is a brief presentation of this historical movement in which the development of

25 "A consistent use of the binary system is also likely to simplify the operations of multiplication and division considerably. Specifically, it does away with the decimal multiplication table, or with the alternative double procedure of building up the multiples of each multiplier or quotient digit by additions first, and then combining these (according to positional value) by a second sequence of additions or subtractions. In other words: Binary arithmetics has a simpler and more one-piece logical structure than any other, particularly than the decimal one" (Von Neumann 1945: 6).

capitalism gave birth to a new form of universality embodied in computers.

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