



Crystals and Analytic Engines: Historical and Conceptual Preliminaries to a New Theory of Machines

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abstract

In this paper I argue that immaterial labor, as defined by its advocates like Hardt and Negri, does not exist. In order to defend this claim I examine how labor has been understood in the history of capitalism through the study of machines, and argue that the most successful theory of machines in capitalist society is Marx's. I rely on this theory to defend my skepticism concerning immaterial labor. However, Marx's theory itself must be defended. One of Marx's most sophisticated critics, Philip Mirowski, has charged him with being 'envious' of two contradictory physics theories at once: the substance-theory of energy of the 1840s and the field-theory of energy of the 1860s. Mirowski argues that Marx could not decide which to take as his model for labor, machines and value, so he used both and ended up with a contradictory theory of value and machines. In Part One of the paper I defend Marx's theory by demonstrating that the very binary Mirowski deploys to criticize Marx's theory (the categories of substance versus field) is not a binary at all and that Marx's theory is consistent. In Part Two I show that Marx's theory of machines is incomplete. Though it included the theory of simple machines and of heat engines, it did not comprehend Turing machines, even though Charles Babbage had developed the first version of a Turing machine thirty years before the publication of *Capital*. This incompleteness encourages thinkers like Hardt and Negri to argue that services, cultural products, and especially knowledge and communication are immaterial products and hence require immaterial labor for their production. A New Theory of Machines that was complete would show how services, cultural products, knowledge and communication are material goods, and thus would support my initial claim.

And in this there is very great utility, not because those wheels or other machines accomplish the transportation of the same weight with less force or greater speed, or through a larger interval, than could be done without such instruments by an equal but judicious and well organized force, but rather because the fall of a river costs little or nothing, while the maintenance of a horse or similar animal whose power exceeds that of eight or more men is far less expensive than it would be to sustain and maintain so many men. (Galileo, 1960: 150)

Introduction

Karl Marx often sardonically noted that the capitalist ethos evoked a magical, 'something for nothing' imaginary concerning the profit-making potentialities of science and machinery. This attitude was precisely captured in the 17th century by Ben

Jonson in his play, *The Alchemist*, and in the 19th century by the get-rich-quick cranks like Charles Redheffer and John W. Keely who had perpetual motion machines and schemes eternally buzzing in their brains (Ord-Hume, 1977). For Marx, capitalists, far from being the sober and rational agents depicted by Max Weber's ideal type, promote an irrational understanding of the uses of machinery, just as capitalism famously inculcates a fetishism with respect to commodities that is more thorough going than the reverence West Africans were supposed to express toward their wooden idols. Far from defining humanity's inevitable future, capitalism is inherently unable to understand the very machines that serve as the distinctive tools and symbols of this supposed future.

In this paper I analyze Marx's theory of machines in capitalism. I do this in order to contribute to the debate concerning immaterial labor that this issue of *ephemera* is devoted to. I take an extreme position in this debate: immaterial labor as defined, for example, by Hardt and Negri in *Empire* – "We define immaterial labor [as] labor that produces an immaterial good, such as a service, a cultural product, knowledge or communication" (Hardt and Negri, 2000: 190) – does not exist. I argue that services, cultural products, knowledge and communication are 'material goods' and the labor that produces them is material as well (though it might not always be tangible). The products of services, from stylish hair cuts to massages, are embodied material goods; cultural products like paintings, films, and books are quite material; communication requires perfectly material channels (even though the material might be 'invisible' electrons); and finally knowledge as presently understood is, like goals in soccer games, a specific material transformation of social reality.

However, in order to make my case, it is not enough to present some counter-examples as I have just done. I need to present a model of work in response to the 'immaterialists' and like all such models, they need a *machine substitute*, for the model of understanding human labor in capitalism is the machine that can replace it in the course of capitalist production. The identification of human labor with the action of machines is a special case of a general situation. Marx doggedly points out, again and again, from the *1844 Manuscripts* to *Capital III*, that capital in the form of machines falsely presents itself as productive of value and the creator of surplus value. Living labor repeatedly appears as dead labor, even in the case of our own living labor. This transformation is not an ideological choice, it is a *reflex* of this mode of life. (This reflex is something like the 'Moon Illusion', i.e., why the moon looks bigger on the horizon than when higher up, transposed from the realm of sight to social understanding.) Marx writes about it in the following passage, "with the development of machinery there is a sense in which the conditions of labor come to dominate labor even technologically and, at the same time, they replace it, suppress it, and render it superfluous in its independent form" (Marx, 1976: 1055). This is one of hundreds of possible citations in Marx's work that makes the same point, illustrating how obsessive he became in trying to expose this false transformation. Indeed, Marx's theory of machines microscopically analyzes this reflex that makes capital 'a highly mysterious thing' and he specifies the conditions of the demystification of machines.

In this paper I defend Marx's theory of machines from charges of inconsistency, but I also find it incomplete. I argue that it needs to be extended to include another category of machine: the Turing machine (i.e. the common mathematical structure of all

computers, formally isolated by Alan Turing in the 1930s) (Turing, 2004 [1936]). A complete theory of machines that included Turing machines as well as simple machines and heat engines would demonstrate, on the one side, the materiality of all labor and, on the other, the lineaments of a strategy to liberate labor from its bondage to capital.

Although Marx was far from being an anti-industrial ‘back to the land’ activist, he was a prime debunker of the economic claims capitalists make for machines which function as a form of conceptual terrorism against workers’ struggle (Caffentzis, 1997). He argued that active human labor is the only source of value, that however cleverly designed or gigantic in size, machines produce no value at all and that, at best, they can only transfer their own value to the product.

Marx’s attitude was similar to that early modern critic of machine magic: Galileo (Galileo, 1960; Drake, 1978). In the same paragraph from which the epigraph of this piece was culled, Galileo ridicules “designers of machines” who believe that “with their machines they could cheat nature” (Galileo, 1960: 150). He claims that machines do not in themselves create force or motion, they simply make it possible to substitute less ‘intelligent’ and less costly sources of force and motion for the more ‘intelligent’ and more costly ones. The problem for the mechanic is to design machines so that “with the mere application of [the mover’s, say, a horse’s] strength it can carry out the desired effect” (Galileo, 1960: 150). The mechanic introduces intelligent design into the world, but s/he cannot add even a cubit of force or motion to it. This might not appear to be so, if one looks at the books of mechanics from Hero of Alexandria’s to Galileo’s own, which are filled with the diagrams of the mediating machines; but its true realm is in the world of costs and wages. In other words, simple machines – the inclined plane, lever, pulley, screw, wheel and axle (capstan) – “judiciously organize force”, they do not create it (Galileo, 1960: 150).

Many physicists after Galileo, especially 19th century architects of Thermodynamics like Sadi Carnot and Hermann von Helmholtz, were anxious to make this anti-magical lesson evident in the context of heat engines as well (e.g., by proclaiming the principles: no perpetual motion machine is possible, energy cannot be created or destroyed).

Marx, undoubtedly influenced by the two ‘laws of thermodynamics’ being developed in his time, agreed with Galileo and, if one substitutes ‘value’ for ‘force’ or ‘energy’, one can see his effort to establish conservation laws for value that block any attempt to ‘cheat society’ with machines. Machines do not create value, they merely ‘judiciously organize’ it and, most important, they make it possible to substitute less costly for more expensive (and/or resistant) labor power. As Andrew Ure, the 19th century ‘philosopher of machines’, wrote: “The effect of improvements in machinery, [lies] not merely in superseding the necessity for the employment of the same quantity of adult labour as before, in order to produce a given result, but in substituting one description of human labour for another, the less skilled for the more skilled, juvenile for adult, female for male....” (quoted in Marx, 1976: 559-560). That is why they can become such powerful weapons against the working class, so that “the instrument of labour strikes down the worker” (Marx, 1976: 559).

Though they appear often to be behemoths of power (as in the steam engines of the 19th century) or angels of intelligence (as in computers of the 21st century), machines' weakness – the fact that they cannot create value – has enormous consequences for the whole capitalist system. Industries that employ a large amount of machinery and a relatively small amount of labor cannot create within their production process the surplus value necessary to constitute an average rate of profit for the investment in constant capital (machinery, for the most part) and variable capital (wages). However, if capitalists do not receive at least an average rate of profit, they inevitably leave their branch of industry over time and new investors shun them. Soon, these branches of industry would stop functioning, due to bankruptcies and low investment. But what if these branches of industry (e.g., oil extraction) were required for the reproduction of the system? How would the profits of such branches be provided for, if the workers in these branches could not generate them? This question is especially important to answer since increasing the use of machinery to respond to workers' struggles is a crucial strategy in the eternally rolling, though often low-intensity, class war.

Marx's response to this conundrum is that there is a transformation of surplus value created in some branches of industry with relatively low ratios of investment in machinery to wages into the profits of branches that have relative high ratios. This process takes place 'behind the backs' of capitalists in the competitive process, and forms the foundation of the remarkable unity of capital, given the apparent competitive character of the system (Marx, 1981: 273ff). Investment in machines is promoted by the system in general, even though it does not lead to an increase in surplus value in particular (although, of course, surplus value can be created by workers in the production of these machines just as in the production of any other commodity).

In Part I of this essay, I defend an important tenet of Marx's theory of machines from claims that it is rooted in a fundamental inconsistency of the theory. This tenet is the notion of a transformation of surplus value generated by some branches of production into the profits of other branches of production.

Part I. Conceptual Preliminary: Is Marx's Theory of Machines Consistent?

I could be a rich man if I could have taken along only what I merely needed to pick up and break loose. In some places I found myself in a veritable garden of magic. What I beheld was formed most artistically out of the most precious metals. In the elegant braids and branches of silver there hung sparkling, ruby-red, transparent fruits and the heavy trees were standing on a crystal base inimitably wrought. One hardly trusted one's senses in those marvelous places and never tired of roaming through those charming wildernesses and delighting in their treasures, on my present journey too I have seen many remarkable things, and certainly the earth is equally productive and lavish in other countries. (Novalis, 1964: 88)

Marx's theory of machines postulates the existence of a fundamental transformation principle of capitalist life: profits tend to be equalized across all branches of industry, even though the ratio between the investments in machinery and the payment of wages varies tremendously between them. If this transformation is not operative, then there would be no incentive to invest in machinery in order to escape working class struggle

or even to ensure the system's own material reproduction. For if surplus value is created by labor, but very little labor is employed in essential industries like oil extraction, then there would be little or no profit for such an industry that requires large investments in fixed capital.

But does such a transformation of surplus value into profit take place literally 'behind the backs' of the participants of the system? The debate on the mathematical and methodological validity of Marx's 'transformation' has been the staple of the academic polemics between Marxists and anti-Marxists since Bohm-Bawerk's *Karl Marx and the Close of His System* (2006) first published in the late 19th century. Indeed, in the last century, every time there was an intensification of the class struggle and a penetration of Marxist intellectuals into the academy, capital's schoolmasters took out that old chestnut from the closet to be roasted again. The sophistication of the technical ripostes on each side, however, has definitely been increasing. Thus in response to the campus rebellions of the 1960s, Paul Samuelson (1971) leveled his analytic arsenal on the old Moor only to find that a whole literature modeling Marx's theory in linear algebraic terms sprouting in its defense. This literature, with its Sraffaian, 'analytic' and 'recursive' solutions, has shown us that the technical problems of the 'transformation' can be resolved *if* one accepts rather stilted mathematical models of Marx's fluid, chemically active description of the capitalist system of production *and* rejects one or more of Marx's conservation principles or mathematical procedures (cf. Steedman et al., 1981; Shaikh, 1978). The status of this debate, therefore, has entered into a more interesting stage. For what is at stake is the very reason for having a labor theory of value in the first place.

A sign of this change appeared with the publication of Philip Mirowski's *More Heat Than Light* (1989) where Marx is no longer charged with making elementary mathematical errors or being ignorant of analytic techniques that were invented a generation or two after the publication of *Capital*. Rather, Mirowski tries to show that the transformation problem is a problem because it reflects a major tension not only in Marx's theory, but in all scientific endeavors during the mid-19th century. Natural philosophy was transforming itself into physics in this period, Mirowski points out, and the ontology of science was turning from 'substance' to 'field' entities (or from 'substance' to 'function' in Cassirer's [1953] formulation).

Mirowski claims that Marx found himself on the 'cusp' of this transition and his value theory reflected it, "in fact there ended being not one but *two* Marxian labor theories of value, the first rooted in the older substance tradition, the other sporting resemblances to nascent field theories in physics" (Mirowski, 1989: 177). The first type Mirowski calls "the crystallized-labor or substance approach", while the second type is called "the real-cost or virtual approach" (Mirowski, 1989: 180). They have very different, even contradictory methodological implications. For the first is like the caloric theory of heat which identified heat as a substance that 'flowed' from hotter to cooler bodies in the way that water flowed from higher to lower elevations, while the second identifies heat as one aspect of a generalized energy field that can be transformed into many different states, phases and forms. Indeed, the intellectual struggle in the development of thermodynamics from the publication of Sadi Carnot's *Memoire* in 1824 to the publication of Clausius' entropy-defining paper of 1865 could be read as marking the

transition from substance to field theories in physics (Carnot, 1986 [1824]; Clausius, 1965 [1865]). Marx's theory then would be like many theories developed in the 1840s by those who accepted both Carnot's caloric explanation of the work performed by the steam engine and early versions of the conservation of energy.

In particular the crystallized-labor theory makes it clear that exploitation can only have its origin in exploitation within the process of production. Since value is a substance, it is conserved both *locally* (when, for example, it is used in productive consumption as in the case of food for a worker or gasoline for a tractor) and *globally* (when the total sum of value is conserved in the complex transformation from one branch of production to another). These flows of value seem to have all the charm of "the hallowed tradition of natural-substance theories, which were intended to imitate the structure of explanation in the Cartesian natural sciences" (Mirowski, 1989: 184). The metaphors emanating from such a view of value, of course, have a powerful political appeal as well, for the sense of theft during the capitalist process of production can be directly referred to. After all, the worker produces a certain amount of value-stuff and s/he only gets part of this value-stuff back in the form of wages, the difference being the only source of the capitalists', the bankers', the priests' and the landlords' revenues.

The problem, Mirowski points out, with such a simple but powerful crystallized-labor theory is that it was *passé* at the moment of its most sophisticated employment in the Marxian critique of political economy. Caloric had been replaced with a much more subtle, field-theoretic entity, energy, whose continuity of motion, metamorphoses, conservation and dissipation was not to be modeled in the fluid dynamics of Cartesian vortexes. This subtlety is illustrated in what Cassirer writes of Mayer's energetic equation of potential with kinetic energy:

If the mere elevation above a certain level (thus a mere state) is here assumed to be identical with the fall over a certain distance (with a temporal process), then it is clearly evident that no immediate substantial standard is applied to both, and that they are not compared with each other according to any similarity of factual property, but merely as abstract measuring values. The two are the 'same' not because they share any objective property, but because they can occur as members of the same causal equation, and thus be substituted for each other from the standpoint of pure magnitude... Energy is able to institute an order among the totality of phenomena, because it itself is on the same plane with no one of them; because, lacking all concrete existence, energy only expresses a pure relation of mutual dependency. (Cassirer, 1953: 199-200)

The 'cost-price' approach was Marx's incipient awareness of this new energetic-field-of-relations approach in his own work. In this approach a commodity can possess a value only relative "to the contemporary configuration of production" (Mirowski, 1989: 181). Thus its value can be changed by, for example, technological alterations anywhere in the economy (e.g., the development of new programming techniques) or even market phenomena (e.g., good harvests) that had no direct connection with the production of the commodity in question (Mirowski, 1989: 181). However, the creation of value can no longer be identified with labor, profit with the exploitation of labor in the production process, nor the flows and transformations of value with continuous (though unobserved) processes. Indeed, in the cost-price world, machines could produce (or deduct) value also. Mirowski suggests that this approach would have solved many of the major analytic problems of Marx's program, though at the impossible cost of "throwing history out the window" (Mirowski, 1989: 184), where by 'history' Mirowski

simply means that present conditions are partly determined by past events and processes.

Let us chart the consequences of contrasting approaches:

Substance theory

Field theory

crystallized labor *approach*

real-cost or virtual *approach*

labor ‘buried’ in the commodity is *source of value*

source of value in the field

the *quantity of value* is determined by labor-time

the ‘socially necessary’ direct replacement costs
determine the *quantity of value*

the history of production is important in the
determination of the value of commodities

the history of production is irrelevant to the
determination of the value of commodities

profit can only be generated in production

profit can be generated in exchange and market
transactions

labor *value is conserved*

‘windfalls’ are ubiquitous and throughout the
system *values* can be created or destroyed
instantaneously

But in trying to juggle between these two inconsistent ontologies Marx was bound to crash, according to Mirowski, who locates this catastrophe in ‘the transformation problem’ where the conservation of crystallized value and surplus value can not be reconciled with the equalization of rates of profit while the cost-price values can easily enforce equalized rates of profit but must falsify the claim that “surplus is only generated in production and is passed around among industries in the pricing process” (Mirowski, 1989: 185). The transformation of values to prices does not pose a mathematical problem *per se*, Mirowski argues, but rather it is a symptom of a deeper logical and methodological incoherence.

This is a serious critique. However, what is charming about Mirowski is that he seems to be relatively innocent of the blatant Cold War motivations that have driven similar efforts in the last couple of generations of scholarly debate on these matters. Indeed, Mirowski’s effort is one of the first in the new post-Cold War turn of a rather hoary genre. A sign that Mirowski is operating in a new critical space is expressed by the fact that he applies to the work of neoclassical theorists like J. B. Clark and, yes, Paul Samuelson the same hermeneutical device he uses to detect tensions and contradictions in Marxism (i.e., the substance versus field approaches). He also finds a shared, root failure in both the Marxist and the neoclassical research programs: *an ill-understood ‘physics envy’ which ironically is often ignorant of the complexity of the object of its envy or is fixated on one historical embodiment of physical theory*. In a word, the contemporary neoclassical research program has become “helplessly locked into the physics of circa 1860” while Marxism is locked in the physics of the 1840s (Mirowski, 1989: 394). Mirowski speaks for a new theoretical initiative that would, on the one hand, open economics up to models of physics that superseded the proto-energetics of

the 19th century and, on the other, look for models outside of physics altogether. But is this type of critique useful in general or accurate as a way of interpreting Marx's writings?

The main problem with Mirowski's hermeneutics in general is that the central distinction between substance and field theories he relies on is far from clear in itself and, furthermore, it is not easily inserted in a historical narrative. First consider theories like Newtonian mechanics, the kinetic theory of heat, the relativity theories and quantum mechanics: are these 'substance' or 'field' theories? Well, they are a bit of both. Thus Newton's gravity acts as a field force, but his notion of mass is substantial; the microscopic billiard balls of the kinetic theory are ideal type substances, but the macroscopic states they create (like temperature, pressure and volume) are field-like entities; Einstein's general theory of relativity seems to posit a substantial character for space-time while his special theory seems to give it a field-like aspect; as for the notorious quantum mechanics, one can easily add a 'substance'/'field' duality to top off and sum up the Tower of Babel dualities it poses to the interpreter. Thus, most theories in physics at least have substance as well as field elements in them and it is in the intersection of these elements that their complex potentialities for paradox emerge: in Newtonian mechanics, the mass point and the gravitational field; in the kinetic theory of gases, the molecule and temperature; in Einstein relativities, the mass point and the manifold of space-time; in quantum mechanics, the wave and the particle. *One might perversely argue that the uniqueness of these theories is to be found in the paradoxical heart of this intersection.*

Thus we see that Mirowski's concepts of 'substance' and 'field' are not found unmixed in any historically given theory in physics. But even as ideal types these concepts are far from mutually exclusive polarities. For one can argue that an ideal field is simply a highly complex substance defined by an infinite set of internal relations while an ideal substance is simply a pure field defined by a small to null set of internal relations. In other words, *the 'substance'/'field' distinction is not one of absolute kind but of dialectical degree.* And in the history of science one can often find nodes of transition from substance to field and then back again. Think of the complex dialectical, crisscrossing dance in the history of quantum mechanics from wave (field) to particle (substance) and back again.

Therefore it is very difficult to use these ontological notions in a historical narrative. From the Newtonian-Cartesian debates of the 17th century to the wave/particle dualities of the 20th, it is clear that 'substance' and 'field' are dialectical polarities in the theory-construction toolbox first of natural philosophy and then of physics. Mirowski credits Meyerson, an early 20th century French philosopher and historian of science, with explaining why the process of reification was so central to science of the post-Aristotelian period. Meyerson showed how 'substance' ontologies underlie conservation laws and these laws make it possible to apply mathematical methods to the "external [but non-celestial] world" (Mirowski, 1989: 6). But substance ontologies have been replaced by field ontologies for equally powerful mathematical reasons, and the reasons for this replacement can hardly be said to be determined by the internal logic of the dialectical spirit.

If Mirowski's 'substance'/'field' dichotomy is not a general tool of theoretical hermeneutics, the question remains whether his critique of Marx and the Marxist theory of value is cogent. Does Marx have two divergent theories of value? Does Marx fetishize labor and in so doing reify it into the very substance-thing that bourgeois economists so superstitiously worship? Mirowski's criticisms certainly reflect the contemporary Zeitgeist, for post-Structuralist critics like Baudrillard reject Marxist analyses because of their purported 'objectivism' and 'representationalism' (Baudrillard, 1975). But are these criticisms accurate? In order to answer this question let us go directly to the center of Mirowski's criticism: *the crystal*. After all, he dubs Marx's substance theory of value 'the crystallized-labor approach' because for Marx, "labor time extracted in the process of production is reincarnated (or perhaps 'buried' is a better term, since Marx calls it 'dead labor') in the commodity, to subsist thereafter independent of any market activity" (Mirowski, 1989: 180). But is a crystal a substance?

At the beginning of the 19th century the crystal became the focus of research programs in mineralogy and in chemistry. Mineralogists saw that most solid inorganic bodies were composed of micro-crystals while chemists, following Haüy, argued that every chemical substance had a unique crystalline structure. Haüy's hypothesis initiated an immense theoretical and empirical activity that eventually ended in its rejection. But these research programs and their fate would undoubtedly have interested Marx (and Engels) not only because they appealed to their general mathematical interests but also because of the role which that most precious of minerals, gold, played in political economy.

By the 1860s a new energetic turn in the crystalline story was taken. It was understood that a mineral's crystalline form was not a given of nature. A crystal was merely "a state of energetic equilibrium reflecting the most stable level of energy under given external conditions" (Paton, 1965: 302). Grove, in a work cited by Marx in *Capital I* (Marx, 1976: 664), clearly makes this point:

There is scarcely any doubt that the force which is concerned in aggregation is the same which gives to matter its crystalline form; indeed, a vast number of inorganic bodies, if not all, which appear amorphous are, when closely examined, found to be crystalline in their structure: we thus get a reciprocity of action between the force which unites the molecules of matter and the magnetic force, and through the medium of the latter the correlation of the attraction of aggregation with the other modes of force may be established. (quoted in Youmans, 1872: 172)

Thus the crystalline aggregation, which had been studied throughout the early nineteenth century as a way of differentiating chemicals, was seen as part of the great round of the correlation of forces. Grove points out that via the correlation of aggregation force and magnetic force a new theory of the crystal is made possible. For the crystal simply is a store of energy that in the various mineralogical processes is released and then reabsorbed. Increasingly the internal structure of inorganic bodies were seen by physicists, chemists and mineralogists as a more or less complex pool of 'tensional' or 'potential' energy.

The whole of the theory of energetics was interested in the relation between this 'potential energy' and the 'actual energy' that is exhibited to the observer. Rankine put

the problematic of energetics in his 1853 paper ‘On the General Law of the Transformation of Energy’ in which he introduces the notion of ‘potential energy’ for the first time:

ACTUAL, OR SENSIBLE ENERGY, is a measurable, transmissible, and transformable condition, whose presence causes a substance to tend to change its state in one or more respects. By the occurrence of such changes, actual energy disappears, and is replaced by

POTENTIAL, OR LATENT ENERGY; which is measured by the product of a change of state into the resistance against which that change is made.

Vis viva of matter in motion, thermometric heat, radiant heat, light, chemical action, and electric currents, are forms of actual energy; amongst those of potential energy are the mechanical powers of gravity, elasticity, chemical affinity, statical electricity, and magnetism.

The law of the Conservation of Energy is already known, viz.: that the sum of all energies of the universe, actual and potential, is unchangeable. (quoted in Truesdall, 1980: 259)

Potential energy is, of course, a typical field variable, since it can change due to variations in the field (whether these changes are gravitational, electrical, magnetic, or chemical) while it can remain static over long periods of time. Actual energy is quite different. It is by its very nature realizing and annihilating itself at its locale of action.

Not surprisingly then, the process of potential turning into actual then back into potential energy was to serve Marx as a model for the shift from living into dead labor that is then transferred in the production process. For example, he refers to commodities “As crystals of this social substance [i.e., human labor], which is common to them all, they are values – commodity values” (Marx, 1976: 128). The crystal is the ideal model for a potential energy store whose structure is formed by the actual energies employed in the crystal-generating process but whose total potential energy is determined by the whole potential field. Value is therefore analogous not to actual, but to potential energy, for labor is valueless while being a creative, transforming, preserving, determining action, but once stored, dead, objectified, determined, congealed labor is value. This dead labor (like its analogous potential energy) is measured by the socially necessary labor-time, not by the living labor that has vanished into time, and is only *represented* in the value of the commodity.

Thus commodities have locked within them value due to the labor (both useful and value creating) that has gone into them. They form the crystalline ‘storehouse’ cave of capital in the same way that Helmholtz describes the objects in “the general store-house of Nature” that lock force within them:

The brook and the wind, which drive our mills, the forest and the coal bed, which supply our steam engines and warm our rooms, are to use the bearers of a small portion of the great natural supply which we draw upon for our purposes, and the actions of which we can apply as we see fit. The possessor of a mill claims the gravity of the descending rivulet, or the living force of the wind, as his possession. These portions of the store of Nature are what give his property its chief value. (quoted in Youmans, 1872: 227)

Just as the potential energy of a rivulet can be changed by shifts in the potential field (e.g. by the reduction of the height of the water’s fall by an earthquake) so too can the value of constant capital engaged in a particular process of production be changed by

events outside of that very process. But the possibility of changes in the potential energy does not turn potential into kinetic energy, for these changes occur, so to speak, 'outside' of the locus of the potential energy. Similarly, changes in the stored value of circulating and fixed capital can occur 'outside' of the process of its production. For example, cotton bought in a previous year and sitting in the storehouse of a spinning mill will increase in value if there is a bad cotton harvest this year, or the value of an already operating spinning machine can decrease if a new less expensive technique for building such machines is put into play. But in both cases these changes take place 'outside' the immediate production process. Within the actual production process of spinning cotton, however, the machine and the cotton "cannot transfer more value than [they possess] independently of the process" (Marx, 1976: 318). Keeping with the analogy, once the potential energy of a body is determined, then the kinetic energy it releases can not be greater than itself.

This excursus into the bowels of Marx's theory of value production and machines is not meant to show that Marx's theory was devised with a strict analogy to energetics in mind. On the contrary, there were many different analogies, metaphors, metonymies, tropes, etc. that Marx had in mind in the composition of *Capital*. Darwinian biology, the infinitesimal calculus, the debates in geology, the developments in organic chemistry and more were often directly and, even more often, indirectly cited in the text. Marx, Engels and indeed much of the workers' movement of the day were not suffering from 'physics envy', rather they were deeply enamored with the tremendous theoretical and practical productivity of the sciences of the day. But certainly pride of place was given to Energetics (or the discipline of Thermodynamics) during the mid-19th century, and it would be surprising if Marx did not explore the relation between labor and energy in his theory. Marx was clearly knowledgeable about Energetics and its primary theoretical distinctions (like kinetic versus potential energy). Therefore, Mirowski's critique of Marx – that he was on the 'cusp' between substance and field theories – is not convincing.

However, we might turn this reply to Mirowski's Marx-critique around into an even more pointed Marx-critique (that is similar to Mirowski's critique of neoclassical economics). Namely, if Marx was perfectly conscious of the anti-substantial developments in mid-19th century Energetics and patterned much of his value theory on them, why should 21st-century critics of capitalism take *his* theory seriously? After all, physics has moved into major new conceptual and methodological territory since the grey beards of thermodynamics finally cracked the contradiction between Carnot's caloric theory and the conservation of energy. Do relativity theory, quantum mechanics, chaos theory not offer better and more interesting insights than labor- and wretch-obsessed Marxism in order to understand the contemporary postmodern situation? Mirowski calls on his colleagues in neoclassical economics to let go of their dependence on outdated (and ill-understood) physical theory and try something new. A similar point has been made by post-Marxists and other 'anti-systemic' thinkers who were previously sympathetic to Marxism.

Well, why not? The answer is simple: *chose whatever model you wish, but what is to be modeled – our social reality – is still rooted in the past*. We cannot avoid or 'go beyond' the categories of labor, value, money, surplus value, exploitation, capital,

crisis, revolution and communism because capitalism is still very much in existence. True, much else is in existence now that was not in the mid-19th century, but has it made a crucial difference in understanding capital? Answers to a question like this are, of course, complex, but who could really say in 2007 that money, work, wages, profit, interest and rent do not *really* matter? Of course they do, and any application of contemporary scientific theory to contemporary social and economic life that ignores them would not *really* matter.

However, there have been genuine changes in the world of machines since the mid-19th century, especially the development and industrialization of the Turing machines. This is an area that definitely calls for an extension of Marx's theory of machines as I will argue in Part II.

Part II. Historical Preliminary: Ure versus Babbage

The Turing Machine is an idealization of the human computer. "We may compare a man in the process of computing a real number to a machine which is only capable of a finite number of conditions... called 'm-configurations'. The machine is supplied with a 'tape'..." Wittgenstein put the point in a striking way: "Turing's 'Machines': These machines are humans who calculate." (Copeland, 2004: 41)

Marx's theory of machines was deeply implicated in the theory of heat engines that was developed in the mid-19th century under the rubric of 'Thermodynamics' in the same way that Galileo's theory of machines was implicated in the theory of simple machines initially developed especially by thinkers in Hellenistic Egypt like Hero of Alexandria and later by Arabic and medieval European mechanicians (Clagett, 1959: 3-68). Indeed, much of the motivation for Marx's restriction of value-creativity to human labor arose on analogy with the restrictions Thermodynamics places on perpetual motion machines of the first and second kind, i.e., on machines that violate the first – conservation of energy – law and the second – entropy – law of Thermodynamics. In this part of the essay I will turn my attention to the kind of machines studied by the theory of Turing machines – often called 'universal computers' or 'logic machines'.

Marx *might* be forgiven for having neglected Turing machines, for the mid-1930s are often celebrated as the origin-time of their theory while World War II is frequently seen as the 'hot-house' that forced the transformation of Turing machine theory into actual, functioning hardware. I qualify what I say because the origin of the theory and practice of universal computers or logic machines *can* be antedated by at least a century. True, the uncertain origin of a scientific or technological concept like that of the universal computer is by no means unusual and in this 'postist' period suspicion of origins is *de rigueur*. But this particular antedating is important for my argument since it will highlight an early tension in Marx's theory that can explain why the later Marxist tradition (in both its Stalinist *and* libertarian tendencies) has traditionally confused the labor process (which they glorified) with the value-creativity of labor.

This case of anteceding origins takes us to a figure quite familiar to Marx and the readers of the pages on machinery in *Capital I*: Charles Babbage. Marx quoted

Babbage's *On the Economy of Machines and Manufacturing* (1832) at least five times in Part IV of *Capital I*, 'The Production of Absolute and Relative Surplus Value' (1976: 643-674) but he seemed to have a rather ambivalent stance toward him. On the one side, Marx credits Babbage with the definition of machine he uses, but on the other, he relegated him to the role of an antiquary, someone interested not in *au courant* Modern Industry (the automatic factory) but rather in *passé* Manufacture (the workshop). In an interesting footnote he compared Babbage to a contemporary of the 1830s, Andrew Ure, whose *Philosophy of Manufactures* (1835) Marx referred to sixteen times in *Capital I*:

Dr. Ure, in his apotheosis of Modern Mechanical Industry, brings out the peculiar character of manufacture more sharply than previous economists, who had not his polemical interests in the matter, and more sharply even than his contemporaries – Babbage, e.g., who, though much his superior as a mathematician and mechanician, treated mechanical industry from the standpoint of manufacture alone. (Marx, 1976: 470)

That is, Babbage was still mired in marveling at the remaining aspects of the detail laborer, at the workshop and handicraftsman work, while Ure was interested in the use of machinery to escape the stranglehold skilled laborers in manufacturing had on capital (Marx, 1976: 563-564).

This assessment is surprisingly off the mark. From the perspective of the 21st century Babbage was clearly involved in a project whose consequences would be more momentous than simply the polemical 'reduction' of skilled into unskilled labor discussed by Ure. For Babbage's work would eventually lead to an understanding of what skill was in the first place (Caffentzis, 1997). However, Marx could be excused his rather conventional assessment of Babbage, since Babbage's very project required an interest in a kind of labor that was not yet within the ken of 'Modern Mechanical Industry' and still required all the resources 'Manufacture' could provide in this period. Babbage wished to build at least *one* universal computing machine out of metal and wire, which required the assemblage of some of the most skilled artisans of Britain to build a machine whose requirements of precision tested the limits of mechanical knowledge. The process of putting together this machine was the basis of his research that went into *On the Economy of Machinery and Manufactures* (1832). As one of his biographers writes:

Babbage's study of machinery and manufacturing processes originally started in a manner so extraordinary that it has passed almost without comment, as if no one could believe what he was really doing: he settled down to study all the manufacturing techniques and processes, more particularly all the mechanical devices and inventions he could find, searching for ideas and techniques which could be of use in the Difference Engine. The manner in which this research led to the elegant devices embodied in the Calculating Engines is itself a fascinating study. (Hyman, 1982: 105)

This 'one step back to go two steps forward' motion was Babbage's fate and Marx was by no means the only one who treated him as a brilliant Victorian quasi-crank. There was evidence enough for his crankiness. For example, when Marx was involved in the process of forming the International Working Men's Association and preparing its London inauguration in September 1864, Babbage was in the heat of his widely publicized campaign against barrel-organists and other street musicians which eventually lead on July 25, 1864 to propose 'An Act for the better regulation of Street

Music within the Metropolitan Police District’ or, ‘Babbage’s Bill’. In support of his campaign, Babbage devoted a whole chapter of his 1864 autobiography *Passages from the Life of a Philosopher* to ‘Street Nuisances’. What follows is Babbage’s description of the chapter:

Street Nuisances

Various classes injured – Instruments of Torture – Encourages; Servants, Beer-Shops, Children, Ladies of elastic virtue – Effects on the Musical Profession – Retaliation--Police themselves disturbed – Invalids distracted – Horses run away – Children run over – A Cab-stand placed in the Author’s street attracts Organs – Mobs shouting out his Name – Threats to burn his House – Disturbed in the middle of the night when very ill – An average number of Persons are always ill – Hence always disturbed – Abusive Placards – Great Difficulty of getting Convictions – Got a Case for the Queen’s Bench – Found it useless – A Dead Sell – Another Illustration – Musicians give False Name and Address – Get Warrant for Apprehension – They keep out of the way – Offenders not yet found and arrested by the Police – Legitimate Use of Highways – An Old Lawyer’s Letter to *The Times* – Proposed Remedies; Forbid entirely – Authorize Police to seize the Instrument and take it to the Station – An Association for Prevention of Street Music proposed. (Babbage, 1968: 389-390)

One can see this cantankerous seventy-tree year old philosopher of machines in 1864 could look a bit ‘off’ not only in the eyes of a communist revolutionary who was in the process of writing the text that refuted the value-creativity of machines and organizing the First International!

But, like it or not, Babbage was working on his Calculating Engines before Sadi Carnot published his *Reflexions on the Motive Power of Fire* (1824) – the beginning of classical thermodynamics – and certainly by 1834 Babbage had theorized the universal computer or, anachronistically, the Turing Machine. Consequently, one cannot say that the theory of heat engines antedates the theory of universal computers. That is, in the period when Carnot was studying, *in general*, the motive power of fire and finding it in “differences in temperature” (Carnot, 1986: 67), Babbage was studying “the whole of the conditions which enable a *finite* machine to make calculations of *unlimited* extent” (Hyman, 1982: 170). The product of that research, Babbage’s Analytic Engine, had the major five components of the modern computer, as Dubbey pointed out:

- (a) the *store* containing the data, instructions and intermediate calculations;
- (b) the *mill* in which the basic arithmetical operations are performed [“control of operations in the Mill is by a microprogram represented by studs on the surface of a barrel (after the manner of a music box or barrel organ)” (Hyman, 1982: xiii)];
- (c) the *control* of the whole operation, in Babbage’s case by means of a Jacquard loom system;
- (d) the *input* by means of punched cards;
- (e) the *output* which automatically prints results. (Dubbey, 1978: 217)

Moreover, the Analytic Engine could repeat instructions, make conditional decisions and store programs in a library. However, the full generality of what a universal computer that recursively operates on its own program could simulate was not fully comprehended at the time by either Babbage or his associates like General Menabrea and

Lady Lovelace. Whereas Carnot presumed the intellectual background of a ‘cosmology of heat’ that identified the determining form of nature and life as an effect of heat (Cardwell, 1972: 89-120), the most that Babbage claimed was that “the whole of the developments and operations of analysis are now capable of being executed by machinery” (Babbage, 1968: 68). Even Lady Lovelace, when it came time for her to employ her most Byronic of hyperboles, could only refer to the mathematical world:

The bounds of arithmetic were however out stepped the moment the idea of applying the [Jacquard] cards had occurred; and the Analytic 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 processes for 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 speedy and accurate practical applications for the purposes of mankind than the means hitherto in our possession have rendered possible. Thus not only the mental and material, but the theoretical and the practical in the mathematical world, are brought into more intimate and effective connexion with each other. (quoted in Babbage, 1961: 252)

That is, Babbage’s engines appeared to be *mathematical* computers and computers were apparently *mathematical* things. True, these mathematical results can have ‘practical applications’, but they are not in themselves ‘practical’. The fact that Babbage’s Analytic Engine was a *universal* computer could not yet connect with a ‘cosmology of computation’ which was, alas for Babbage, to be the creation of the mid-20th century. Was this failure inevitable? The cyber-punk novelists William Gibson and Bruce Sterling in *The Difference Engine* (1990) did not think so, since they imagined a Victorian world where the connection between the computer and the steam engine was made and materialized in a complete mode of capitalist production. If their novel shows us that this gap was not inevitable, since the connection was imaginable, then why was it not made?

Here are parts of the answer as to why Marx, along with the British Government and ‘venture capitalists’ after 1834 and almost everyone else, ignored Babbage’s engines in the 19th century: (a) they were conceived, even in the most florid of settings like the one above, as mathematical instruments; (b) the crisis of clerical labor had not yet materialized; (c) the computational aspect of all labor processes had not yet been understood. For in the mid-19th century the heat engine and not the computer stood at the center of Modern Industry’s factories, as Ure lyricized, “In these spacious halls the benignant power of steam summons around him his myriads of willing menials [and assigns to each the regulated task, substituting for painful muscular effort on their part, the energies of his own gigantic arm, and demanding in return only attention and dexterity to correct such little aberrations as casually occur in his workmanship]” (the unbracketed part is quoted by Marx [1976: 545] from Ure [1967: 18]).

Clerical, or mathematical labor, also appeared to be a rather minor aspect of Modern Industry closeted away somewhere in a dusty office above the behemoth of steam on the factory floor. Indeed, such labor gets barely a mention in Babbage’s own *On Economy of Machinery and Manufactures* (cf. Babbage 1832: 176-177). Consequently, Babbage’s Engines could be relegated to the status of an item on a scientist’s or

mathematician's 'wish list' as late as 1878 when a prestigious committee of the British Association for the Advancement of Science advised, "not without reluctance", the Association not to invest any funds in building one of them (Hyman, 1982: 254). Whereas the colossi of steam were on the minds of 19th century industrialists, military strategists and revolutionaries, the machines of computation were considered purely supplementary to the serious work of industry.

This estimate was to change in the transition from the paleo-capitalistic period of absolute surplus value to the contemporary period of transferred surplus value (Caffentzis, 1992: 232-238). A mark of such a change can be found in the changing position of clerical groups within the composition of the waged working class between the mid-19th and mid-20th centuries. As Braverman pointed out:

The census of 1870 in the United States classified only 82,000 – or six-tenths of 1 percent of all 'gainful workers' – in clerical occupations. In Great Britain, the census of 1851 counted some 70,000 to 80,000 clerks, or eight-tenths of 1 percent of the gainfully occupied. By the turn of the century the proportion of clerks in the working population had risen to 4 percent in Great Britain and 3 percent in the United States; in the intervening decades, the clerical working class had begun to be born. By the census of 1961, there were in Britain about 3 million clerks, almost 13 percent of the occupied population; and in the United States in 1970, the clerical classification had risen to more than 14 million workers, almost 18 percent of the gainfully occupied, making this equal in size, among the gross classifications of the occupational scale, to that of operatives of all sorts. (Braverman, 1974: 295)

This change in the size of the clerical work force from the mid-19th to the mid-20th century, however, took place with a concomitant change in its predominant gender (from male to female) and its relative wage (from about twice the average wage for factory operatives to below the operatives' wage) (Braverman, 1974: 296-298). This transformation could not have happened without a substantial change in the machinery of the office, most especially in the use of computers. And it was imperative that this change take place for all of capital since, for example, a sudden doubling of the wage of almost twenty percent of the work force *ceteris paribus* would have meant a twenty percent increase in the total wage bill itself and potentially a substantial drop in profit. This gradual wage crisis of clerical labor, therefore, put a premium on the development of computing machines that would subvert the wage demands of a highly skilled part of the working class. But this crisis was not yet even on the horizon in the 1830s nor, indeed, even by 1867. Babbage's Analytical Engines could not attract the sustained attention of the capitalist class' 'central committee' until the dimensions of the crisis of clerical labor began to appear, which was not to happen for more than half a century after *Capital I*'s publication.

But a more important source of the neglect of Babbage's Engines was that neither Babbage, nor Marx, nor anyone else at the time saw the essential connection between computation and *all* forms of the labor process; even though the key was staring Babbage and Marx in the face all along. That key was Jacquard's loom. It proved essential, as mentioned above by Lady Lovelace, for the creation of the Analytical Engine or the universal computer. The problem was that this transposition was taken by Babbage as that of an industrial device being used for mathematical purposes while Marx (following Ure) saw it as one more chapter in the continuous saga of the struggle between workers and machinery (Marx, 1976: 553-564). This is not to say that either

was wrong *per se*, i.e., Jacquard's device was implicitly a mathematical device *and* explicitly a weapon in the industrial class struggle, but rather that Babbage's *transposition* of the two itself marked a moment in the self-reflection of the labor process that was not understood until the 1930s.

Let us consider more extensively each part of the matter:

First, Babbage described the role of the Jacquard loom in the development of his Analytic Engine in the following passage:

It is known as a fact that the Jacquard loom is capable of weaving any design which the imagination of man may conceive. It is also the constant practice for skilled artists to be employed by manufacturers in designing patterns. These patterns are then sent to a peculiar artist, who, by means of a certain machine, punches holes in a set of pasteboard cards in such a manner that when those cards are placed in a Jacquard loom, it will then weave upon its produce the exact pattern designed by the artist. Now the manufacturer may use, for the warp and weft of his work, threads which are all of the same color; let us suppose them to be unbleached or white threads. In this case the cloth will be woven all of one colour; but there will be a damask pattern upon it such as the artist designed. But the manufacturer might use the same cards, and put in the warp threads of any other colour. Every thread might even be of a different colour, or of a different shade of colour; but in all these cases the *form* of the pattern will be the same – the colours only will differ. The analogy of the Analytic Engine with this well-known process is nearly perfect....The Analytic Engine is therefore a machine of the most general nature. Whatever formula it is required to develop, the law of its development must be communicated to it by two sets of cards. When these have been placed, the engine is special for that formula. The numerical value of its constants must then be put on the columns of wheels below them, and on setting the Engine in motion it will calculate and print the numerical results of that formula. (Babbage, 1961: 55)

Or as Lady Lovelace put it, “the Analytic Engine *weaves algebraical patterns* just as the Jacquard-loom weaves flowers and leaves” (quoted in Hofstadter, 1980: 25). Thus, Babbage and Lovelace saw in the Jacquard loom principle – that of using *seriatim* a set of partial instructions to weave a total textile – a *form* that could be transposed into a mathematical space of operations on numbers in order to mechanize them. But for Babbage and his supporters the connection between the Jacquard loom and the Analytic Engine was exactly that, a *transposition* from an industrial setting to a mathematical one, instead of an indication of a third, mathematical-industrial space that characterized the labor process in general. This insight was lacking, of course, not only in Babbage and Marx but also in most of those who studied the labor process until the 1930s. For example, Taylor's ‘scientific management’ efforts of the turn of the century were still engaged with the time-and-motion studies that linearly fractionalized the work process in order to reduce its temporal components in order to speed up the whole. But Taylorization left the deep computational structure of the labor process unexamined.

Second, Marx, following Ure, saw in Jacquard's loom another “invention... supplying capital with weapons against the revolts of the working class” (Marx, 1976: 563). Jacquard's loom was surely that, for it was aimed against one of the most militant parts of the European working class, the Lyons silk workers. As a commentator on ‘the artisan republic’ of Lyons pointed out:

In the eighteenth century, the silk industry, or the *fabrique*, had become a capitalistic putting-out system with a few hundred merchants commissioning a few thousand master weavers to produce the silk. Masters' dependence on merchants' hiring and piece-rate (or wage) practices forged a

bond of solidarity between masters and their 'employees' or journeymen. One consequence was a tradition of economic militance. As early as 1709, silk weavers boycotted merchants to get higher piece-rates; in 1786 and again in 1789 and 1790, they struck for a general piece-rate agreement... [After the Revolution] silk workers and local authorities returned to the *ancien regime* concept of collective contracts guaranteed by the government in 1807, 1811, 1817-19 and 1822. Moreover, silk workers formed authorized voluntary versions of their old corporations and used these mutual aid...societies as covers to organize strikes. (Stewart-McDougall, 1984: xiv-xv)

In the face of such a historically intransigent sector of workers Bonaparte and Lazare Carnot (Sadi's father), according to Ure, set Jacquard to work to develop a loom that would circumvent the skill of the silk weavers:

[Jacquard] was afterwards called upon to examine a loom on which from 20,000 to 30,000 francs had been expended for making fabrics for Bonaparte's use. He undertook to do, by a simple mechanism, what had been attempted in vain by a complicated one; and taking as his pattern a model-machine of Vaucanson, he produced the famous Jacquard-loom. He returned to his native town [Lyons], rewarded with a pension of 1000 crowns; but experienced the utmost difficulty to introduce his machine among the silk-weavers, and was three times exposed to imminent danger of assassination. The *Conseil des Prud'hommes*, who are the *official* conservators of the trade of Lyons, broke up his loom in the public place, sold the iron and wood for old materials, and denounced him as an object of universal hatred and ignominy. (Ure, 1967: 256-257)

All this pre-Luddite rage in 1807 was not misconceived. The Jacquard punch-card device "halved the time needed to mount the looms, eliminated the weaver's helper, and quadrupled productivity," hence reducing piece-rates, and by 1846 about one-third of the silk looms in Lyons had Jacquard devices (Stewart-McDougall, 1984: 12). Ure, of course, took the resistance of the silk weavers of Lyons to the Jacquard loom as a typical short-sighted response of the workers to the inevitable and beneficial consequences of mechanization, although Ure also notes later: "it appears that there has been a constant depreciation of the wages of silk weaving in France, from the year 1810 down to the present time [1835]" (Ure, 1967: 264). But this action and reaction of the classes around the Jacquard loom was just another moment in a more general struggle that would, Ure was sure, be won by an alliance of capital with a properly chastened working class.

Ure and Marx, who inversely followed him, saw in the transition from Manufacture to Modern Industry a *general process*: "to substitute mechanical science for hand skill, and the partition of a process into its essential constituents, for the division or graduation of labour among artisans" (Ure, 1967: 20). But this description is rather vague and infinitely variable in its realization. For the questions, '*How* does one substitute mechanics for hand skill?' and '*What* are the essential constituents of a labor process?' are open ended. Neither Ure nor Marx saw that this substitution could have a specifically identifiable character that would at the same time be universalizable, aside from its being reducible to abstract labor through the labor market in the case of Marx. And therefore the realization that Babbage's induction of the Jacquard principle into the mechanization of mathematics had within it a general description of the labor process remained stillborn.

This insight was to be the result of the theory of Turing machines and the concomitant 'cosmology of computation' generated in the 1930s and 1940s. By then a number of new factors had come into play: (a) mathematics itself had been remarkably

generalized; (b) the wage crisis of the clerical working class had matured; (c) the limits of a time-and-motion form of analysis of the labor process had been reached in the formation of the Congress of Industrial Organizations (CIO) and other forms of ‘mass worker’ class organization. Thus the stage had been set for a new theory of computing machines and the labor process, or, more precisely, the self-conscious application of Babbage’s forgotten, never fully cognized theory of universal computation.

Conclusion: A New Theory of Machines or an Old Theory of Capitalism – or Both?

The result of these conceptual and historical preliminaries is apparently a contradiction. On the one side, Marx’s hoary theory of the role of machines in capitalism is vindicated as internally consistent against the claims of critics like Mirowski; on the other side, Marx’s theory of machines is clearly found to be incomplete, since it does not explain how the introduction of Turing machines (the descendants of Babbage’s Analytic Engine) affects the work process, the generation of surplus value and modalities of class struggle.

Philip Mirowski argues that both Marxist and bourgeois economics should question their allegiance to theories patterned on old theories of physics that have been left behind in the 20th century. But this argument, as I showed in Part I, is invalid. However, Mirowski does have something right. There *is* a tension between the old and new in our historical condition with respect to science and machines that needs to be isolated and resolved. It is simply that the enormous productivity (and violence) brought about by introducing a new order of machines into the work process is putting even more stress on the categories of capitalist (and anti-capitalist) self-understanding. It is important at this juncture not to appeal mindlessly to that old Marxist chestnut, ‘the contradiction between the forces and relations of production’, and leave it at that. For this contradiction, as Mario Tronti pointed out long ago, does not necessarily lead to another post- and anti-capitalist system of production, as Marx envisioned (Tronti, 1972). Indeed, in most cases it merely stimulates the development of capitalism itself.

Therefore, Marx’s consistent but incomplete theory of machines in capitalism needs to be extended to the realm of Turing machines. One immediate consequence of this extension would be a new conception of the powers of the labor process itself and the manner by which surplus value is created. For this process and its powers are inherently neither immeasurable nor subversive, nor is it a tale of ‘immaterial labor’ as some have recently argued (Hardt and Negri, 2000).

How would the new theory of machines that I described help support my claim that there is no immaterial labor? It would show that contemporary technology is haunted neither by ‘magical’ forces nor mysterious ‘ideational’ novelties. What appear to be ‘immaterial’ products of labor are the result of pattern production that can be accomplished by machines (whether they be composed of wood, iron and paper cards and powered by heat engines or of plastic, silicon and copper and powered by electric currents). These machines are fully ‘physical’ or ‘material’, in the usual senses of these

words, as are the patterns they produce and, most importantly, reproduce. For at the core of capitalist commodity production is the reproduction of a pattern, whether it be ‘composed’ of pure silk or pure electrons. A new theory of machines would help explain the capitalist consequences of the ability to produce these patterns mechanically.

The Lyons artisans who smashed the Jacquard looms recognized a truth important for the class struggle that should be inscribed in such a theory. Machines can reproduce the patterns that they – intelligent and creative humans – weaved. Millions of artisans, craftspeople, engineers, clerks, and computer programmers have learned the same lesson since. No reproducible commodity production is essentially unmechanizable.

As a corollary, the new theory of machines would definitely provide a critique of ‘immaterial labor’ as defined by Hardt and Negri. To see this let us review the three types labor they unite under the rubric of ‘immaterial labor’: (1) “the production and manipulation of affects and requires (virtual or actual) human contact, labor in the bodily mode;” (2) “an industrial production that has been informationalized;” (3) “the immaterial labor of analytical and symbolic tasks, which itself breaks down into creative and intelligent manipulation on the one hand and routine symbolic tasks on the other” (Hardt and Negri, 2000: 293).

Of course, Hardt and Negri are free to coin any term they wish to express their insights. They seem to have chosen ‘immaterial’ – an adjective fraught with metaphysical and political baggage – as a way of differentiating their view of capitalism from the ‘materialist’ Marxist tradition. In making this choice, however, also they enter into a field with a history of its own that needs to be considered. For example, after the women’s movement’s long struggle to have ‘housework’, ‘reproductive’ work and the body be recognized as central to the analysis of capitalism, it is discouraging to have two men come along and describe the very embodied results of reproductive work done largely by women as ‘immaterial’! Indeed, we see this tension in their very definition of this kind of immaterial work, “labor in the bodily mode” (2000: 293). The dissonance between immateriality and a bodily mode should alert us to a problem in using a term like ‘immaterial labor’.

The new theory of machines would give further support for a critique of the term ‘immaterial labor.’ After all, the very distinction between ‘intelligent manipulation’ and ‘routine task’ that is so important to Hardt and Negri is put into question by Turing Machine Theory as is the notion that analytic and symbolic tasks are inherently irreducible to perfectly mechanizable operations. Turing exorcized “the ghost from the machine” more than half a century ago, Hardt and Negri’s return to a Cartesian mind/body, material/immaterial rhetoric would re-“spiritualize the machine” at the cost of a great confusion (Kurzweil, 1999). Moreover, the notion that information is ‘immaterial’ was successfully countered in the development of Information Theory (again more than half a century ago) that saw information as the inverse of entropy (Weiner, 1961). The fact that information, like entropy, is not ‘tangible’ does not mean that it is not ‘physical’ (and hence it is not ‘immaterial’).

Let me return, then, to my initial claim: *immaterial labor does not exist*. I simply mean by this two things. First, the adjective ‘immaterial’ participates in a binary semantic field (immaterial/material) that provokes a philosophical discourse that has been problematic for centuries. Are we to return to the Aristotelian/Platonic debates on the relation between form and matter or begin to argue about whether a ditch is immaterial (and hence whether ditch-digging is ‘immaterial labor’)? Following Hardt and Negri and the other theorists of ‘immaterial labor’ into that field would not be a wise ‘exodus’ for the anti-capitalist movement. Second, the term ‘immaterial labor’ fails to bring out important common features of labor like housework and computer programming. It is not that Hardt and Negri and other ‘immaterialists’ do not find commonalities between housework and computer programming, rather the *kind* of commonalities that they find are not useful to understanding the class struggle at this period in history. Thus, their inability to find measurable value production as a commonality between these two forms of labor is a decisive problem in their work.

However, Hardt and Negri are right in insisting on the importance of the Turing machine for 21st century struggle. As with all machinery, the Turing machine defines a terrain of struggle with its own landmarks and history that are still in formation. A new theory of machines that brings together simple machines, heat engines and Turing machines would make it possible to survey this terrain and go beyond simply noting the continued existence of the contradictions and conflict between worker and machine in 21st century capitalist production.

I hope my preliminary efforts here will invite others to join in the work.

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