Labor, Energy and the Colonial Geography of Artificial Intelligence

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ABSTRACT

This article attempts to place the energy-intensive project of mechanizing interpretive labor known as artificial intelligence (AI) in the context of the longer trajectory of post-18th century industrialization and the capitalist appropriation of human and nonhuman work. Insisting on the material nature of mental work, the physical nature of information, and the political nature of thermodynamics, the article proposes viewing AI, like more conventional forms of industrialism, as a set of entropic, globally-distributed machines for labor exploitation concentrated in private hands and dependent on specific geographic patterns of colonialism and ecological fatigue. In particular, it examines the contradictory relations through which interpretive 'dead labour' crystallized in AI machine networks and platforms recruits, partners with, and degrades enormous quantities of both 'living labour' and thermodynamic energy in order to perform its repetitive tasks. As with the 'heteromation' (Ekbia & Nardi, 2017) involved in the 19th-century industrial revolution, the geography of this process is better understood by treating energy not as a singular resource extractable from various zones and then used up in other zones of an essentially invariant landscape, but as the political reorganization of entropy gradients and exchanges across the borders of nonequilibrium systems. In this way, the article aims to contribute to a historical understanding of the 'digital natures' that AI shapes and the living labor that helps constitute it.

Keywords: artificial intelligence, labor process, energy, thermodynamics, cognition, capitalism

1. Introduction

This article develops two insights about artificial intelligence (AI) together in the hope that the combination may help in understanding contemporary political struggles. The first insight is that 21st-century AI consists of energy-intensive forms of mechanization that are continuous with those of 19th-century phases of capitalist industrialization and shares many of their social and ecological characteristics. In both periods, mechanization functions not to eliminate labor but to change the way it is exploited and boost capital's take of the surplus value it creates either by raising productivity or by lowering the cost to capital of labor's subsistence. The wave of conventional fossil-fuelled capitalist mechanization that began in the 19th century (and continues today) has both facilitated and exploited the global spread of wage and slave labor. The archetypal "hidden abode" (Marx, 2004 [1867]: 279) where value has been produced for capitalists is the labor process within 'jobs' salaried by the day, hour, week or year in specific, organized 'workplaces,' integrated, as much recent Marxian analysis has contended, into a wider, continuously-reorganized support system of enclosure, extraction, slavery, unwaged care work, plantation agriculture, state subsidies, monetary discipline, patriarchy, white supremacy, ecological devastation and expansion and re-creation of frontiers of appropriation (James & Dalla Costa, 1972; Federici, 2021; de Angelis, 2006; Svampa, 2015; Horne, 2020; Gilmore, 2006; Cooper & Burrell, 1988; Böhm & Land, 2012; Fraser, 2014, 2021; McMichael, 2015; Moore, 2015; Walker, 2016; Wolford, 2021). Contemporary AI has left unchanged this basic pattern of value extraction from living labor reinforced by ever-increasing debilitation of the nonhuman world. However, it has introduced several adaptive novelties into the structure. First, it is making a much more thoroughgoing attempt to mechanize the deeper layers of laboring capacities than previous industrial revolutions did. These layers include extremely basic human abilities to recognize, to interpret, to desire, to perceive, to infer, to learn, to calculate, to remember, to find one's way in a landscape, and so forth – the layers that ground labor power as a whole (Lohmann, 2020). The point is to go beyond automating skills such as spinning or weaving toward mechanizing the capacities to build and maintain the interactions and collective subjectivities (MacKenzie, 1984) that underlie capitalist work and consumption itself. In the typical contradiction that has always afflicted industrial capital, however, this putative 'displacement' of human labor power by machines turns out in the end to require the recruitment of yet more of it, in this case in its most basic forms. This necessitates a second innovation of AI: cheap new means by which capital can get bulk access to the needed living labor power. Appropriately to an age of growing precaritization, casualization and systematic worldwide assaults on 'inefficient' salary and benefit contracts (McMichael, 2015), these means go far beyond the conventional wage paid to workers for time spent in conventional workplaces. They include crowdworking and social networking platforms tied to global networks of sensors and 'hand digitizers' in the form of smartphones and laptop computers, linked and coordinated via an archipelago of energy-intensive giant data centers housing hundreds of thousands of speedy computer processing units. Heavily subsidized, the new machine networks have become tools for capital to extract myriad tiny bits of surplus from human activity around the globe at the lowest possible unit price, which, in the case of the distributed 'surveillance extraction' of unpaid human activity (Zuboff, 2019), is zero or negative. The results, valorized above all by being used to manufacture micro-predictions that can accelerate circulation of the maximum volume of goods and services, include a further capitalization and 'real subsumption' of commons and social life and a further blurring of distinctions between 'workers' and 'nonworkers,' between 'worksites' and 'zones of reproduction,' and between 'employed populations' and 'reserve armies of labor.' Another typical set of contradictions follows on, when the material or social bases nurturing the labor power that capital itself needs are eroded and decomposed in ways that can be both conventional (ecological degradation, human burnout) and less so (new forms of mineral extraction and associated waste accumulations, loss of wayfinding or programming skills). In short, just as the transition to wage labor tended to move the locus of exploitation into a "hidden abode" mingling necessary and surplus work in the capitalist labor process, capital's current efforts to push beyond the conventional wage are opening "hidden abodes" in still more concealed, yet globally-scattered locales where a workforce of many billions finds itself "stepping to the side" (Marx, 2004 [1867]: 497) of the production process involving the new industrial machines that constitute AI. Opening these new hidden abodes to view (Böhm & Land, 2012) requires analytic efforts parallel but additional to those that Marx applied to the first industrial revolution (see Table 1 below).

The second insight that this article attempts to develop is that it will be easier to understand the human and extra-human ecological dimensions that 19th- and 21st-century mechanization share if energy is conceptualized not as a timeless resource that can be located, extracted and depleted, but rather as an industrial revolution-era development whose key feature is the geographic and political reorganization of entropy slopes. The idea is that the practice and theory of energy since the 19th century involve:

(1) Continuous efforts to reorganize the earthly gradients between low and high entropy that are needed to sustain proliferations of energy conversion devices needed by industrial machines, including by AI devices;

(2) Accelerated erosion of these gradients within certain bounded systems; and

(3) Expansion of colonial management across those borders to dispose of high entropy and curb trends toward local thermodynamic equilibrium.

This redefinition of energy adds both precision and detail to standard descriptions of the links among labor exploitation, mechanization and geographic change.

Put together, these two insights suggest a research program into AI as a network of entropic, globally-distributed machines for new types of labour exploitation and control linked – as previous capitalist machine networks have been – to particular geographic patterns of racism, patriarchy, colonialism and ecological degradation. By investigating AI as an emerging politics of human and nonhuman geography, the paper tries to help identify effective points for radical popular intervention in an emerging world of 'digital natures' and their associated contexts of precarity, microwork, debt, skyrocketing energy development and turbocharged extractivism.

The plan of the article is as follows. The second section recaps the case that post-18th-century capitalist mechanization neither renders human labor obsolete nor, on the whole, lightens its load. Following Marx, it contends that instead of machines replacing humans, machines and humans become paired under industrial capitalism in a constantly-changing dynamic in which productivity, labor discipline and centralized private ownership of means of production are intrinsically linked with growing fatigue and dismemberment of commons, health, and earth systems (Caffentzis, 2013), necessitating the expansion of frontiers in multiple directions at once (Moore, 2015). Extending Marx, it notes that what Cara Daggett (2019) calls the 19th-century 'birth of energy' exemplifies, develops and expresses this productivity/exhaustion dialectic in the form of the tension between the First and Second Laws of Thermodynamics. Drawing on recent work in nonequilibrium thermodynamics, it goes on to propose a geographic reconceptualization of modern energy as a continual colonial rearrangement of entropy slopes rather than as a pattern of resource extraction and depletion.

The third section places AI within this history of shifting, adaptive patterns of intensive, mechanized extraction of surplus from human and more-than-human nature. It argues that while contemporary AI, like more conventional industrial machine networks, does not replace living human labor, it does develop new ways of extracting relative surplus value from the billions of workers that it needs to feed data into the convolutional neural networks and other AI devices supposedly designed to automate seeing, identifying, interpreting, wayfinding and other core laboring skills. The inability of the massive prediction-making apparatus that results to supplant human work as a whole is in the end of no more practical import to capital than the similar incapacity of 19th-century factory machines to do so. Its quotidian utility lies in the profitable mass production of isolated behaviors such as matching images with symbol strings, matching 'equivalent' symbol strings in different languages, matching products to individual consumers, matching price patterns to investment, matching chemical structures to economic opportunities, matching contract clauses to possible outcomes and so forth. Nevertheless, the ideology and fantasy of 'AI replacing humans' is extremely important to capital as a threat to labor, a research inspiration, and, perhaps most important, as a means for covering up the immense and increasing quantities of human labor that are, in fact, required to keep AI machines going. This is why it is important to take some time to understand the fallacies involved.

Shunning Cartesian dualisms between material/immaterial or manual/intellectual work, the article's fourth section takes up this task by trying to break down analytically unhelpful divisions between the industrial revolution's mechanization of 'manual' skills like weaving and AI's mechanization of 'cognitive' abilities like recognition, translation, calculation, wayfinding, inferring and so forth.

That, it argues, can in turn facilitate a sharper focus on (1) continuities and transitions in procedures of labor exploitation and control during the past two centuries, (2) the dependence of both forms of mechanization on 19th-century thermodynamic energy and (3) their shared and closely-related colonial geographies. The section focuses on five overlapping perspectives that, taken together, can go some way toward explaining why AI is not a substitute for living labor and does not create value for capital. First, AI's acts are not holistic in the ways required for capital accumulation. Second, AI claims to the status of living labor are based on the fallacious notion of a self-interpreting rule or image. Third, AI is not designed to cope with cause and effect as living workers do. Fourth, AI time is not the time of living labor. Fifth, attributing living labor status to AI is, in revealing ways, fetishism. Because this section's exercise in 'de-Cartesianization' relies on research that crosses normal academic divides, a table is included that attempts to help specialists link together some pertinent work in linguistics, philosophy, history, anthropology, developmental psychology, sociology, literary studies and computer science (Table 1).

The article's fifth section then lays out some of the consequences for energy and energy landscapes. The section stresses that it is no accident that ecological debilitation is a common feature of 19th-century industrial capitalism and 21st-century AI, and that AI's exorbitant energy use cannot be a matter for mere incremental reform or regulation, however well-intentioned. A final section draws togther some threads and expresses the hope that the article's geographical understanding of 21st-century mechanization of interpretive work can help social movements, academics and journalists resist the fetishization of AI devices (and indeed industrial machines more generally) that remains so common today. This understanding, the section argues, can also help elaborate, redefine and renew Marx's notion of living labor in a way useful for analyzing contemporary class politics.

2. Industrial revolution machines and their energy geography

One key takeaway from two centuries of close observations of capitalist society (Shelley, 1813; Mill, 1848; Linebaugh, 2012; Gray & Suri, 2019) is that conventional industrial machine networks neither render living human labor obsolete nor tend to lighten the toil of human beings "not fed by other people's labor" (Marx, 2004 [1867]: 492). In global terms, on the contrary, they have contributed to the expansion of the volume of both waged (Huber, 2009) and unwaged (Moore, 2015) capitalist work, generally of debilitating kinds. While machine networks have always driven workers out of particular sectors, expanding those networks profitably has entailed an aggregate global *increase* in the intake of living labor across the economy as a whole (Marx, 1894; Caffentzis, 2013; Moore 2015). Since the dawn of the microcomputer age around 1980, the growth of capital's planetary labor force has more than kept pace with population growth (World Bank, 2013, 2022). The conjunction of an increased mass of industrial machines with accelerated use of coal along the coast of China at the close of the 20th century was accompanied by one of the largest and fastest expansions of the global proletariat in history (Li, 2011; Malm, 2012). Migrants have swelled urban and export zone employment elsewhere as well, while female waged employment and labor along supply chains have jumped, too. At the same time, growth in the mass of computing machinery supporting the 'smart economy' has been fed by an unprecedented though difficult-to-quantify spread of both paid and unpaid labor-intensive piecework such as image labeling, image censorship, label correction, translation revision, site rating, page ranking and other forms of algorithm training and tweaking. As Lilly Irani (2015) notes, living human labor has continually proved to be necessary to "configure, calibrate, and adjust automation technologies to adapt to a changing world, whether those changes are a differently shaped product or a bird that flies into the factory" (see also Gray & Suri, 2019; Chen & Cassidy, 2017; Ekbia & Nardi, 2017; Jones, 2021).

Nor is automation inside any particular industrial sector capable of dispensing entirely with human workers even within that sector (MacKenzie, 1984; Collins & Kusch, 1998; Irani, 2015; Gray & Suri, 2018; Lohmann, 2021c). Whether the "automatic" devices in question are situated on car assembly lines or in data centers, infusions of living, often highly-qualified human work are always required to "comb the machines" (Carbonell, 2018) – to feed, watch, maintain and repair them, correct their failings, prevent accidents in increasingly fragile and unpredictable complex systems (Pfeiffer, 2016), clean, annotate and curate data (Jones, 2021), link mechanical devices with social needs, and so forth. Indeed, a better word for automation under capitalism generally might be the useful term that Hamid Ekbia and Bonnie Nardi (2017: 16) have coined in order to understand better the political economy of computer networks in particular: *heteromation*, or a machine-mediated response to the tendency of the rate of profit to fall that necessarily includes large injections of human work. Other neologisms that helpfully steer attention away from the false connotations of 'automation' include *fauxtomation* (Taylor, 2018), which calls attention to the ways that 'automation' functions to conceal the living labor on which it always depends (see also Schaffer, 1994; Collins & Kusch, 1998; Collins, 1990; Suchman, 2006: 245 ff.; Irani, 2015), and *niggermation* (Georgas & Surkin, 1998), a term emerging out of the struggle of auto workers in Detroit in the 1960s, who found that increases in productivity attributed to factory 'automation' entailed more brutal exploitation of living labor, mostly black. To put the point historically, it is misleading to say that any human skill has ever been fully mechanized – whether weaving, spinning, steelmaking, papermaking, farming or anything else – if that implies machines taking over such a skill in its entirety while leaving everything else exactly as it was, in particular the production of capitalist value (Caffentzis, 2013). In this sense, weaving machines do not weave and spinning machines do not spin. Nor, as Marx (2004 [1867]) pointed out, do human weavers or spinners disappear during so-called automation; instead, they may well reappear among other workers who are employed to step "to the side" (497) of the machine as its necessary "appendages." In sum, the propaganda heralding a hypothetical future 'end of work' that has been repeated throughout the last two centuries down to the digital age (Kurzweil, 2005; Brynjolfsson and McAfee, 2014; Bostrom, 2014; Domingos, 2015; Ford, 2015, Srnicek and Williams, 2015; Frase, 2016; Yang, 2018; Bastani, 2019; for recent criticism see Carbonell, 2022; Jones, 2021; Benanev, 2019 and Pfeiffer, 2016) has always been brought up short by the realities that (1) on a global scale, increased machine mass is correlated with increased recruitment of human activity for capital accumulation, and (2) no industrial or digital machine has ever been clever enough to relieve capital, even within particular economic sectors, of the need to struggle against the resistance offered by the human labor that it requires to function.

Two accompaniments of this twinned expansion of what Marx (1867) called the 'dead labor' crystallized in centrally-owned machines and the living labor required to 'animate' it for capital are first, the historical development of various capitalist divisions of labor and second, the scientific energy revolution of the 19th century. These accompaniments are likewise twinned. It is only when human activity is altered and subdivided or decomposed along certain lines for productive and supervisory purposes that it becomes logical to replace some tools with machines, institute further changes in the subdivided bits of production, and develop and apply a uniform, abstract energy to some of the altered parts in indefinitely augmentable quantities. As Marx (1867) notes, it was growth in divisions of labour and mechanical organization that invited a 'mightier moving power than that of man', not the other way around: 'The steam engine itself … did not give rise to any industrial revolution. It was, on the contrary, the invention of machines that made a revolution in the form of steam engines necessary' (497). A crucial part of that latter revolution – though one that Marx and his followers, unfortunately, have seldom elaborated upon – was the development of the science of thermodynamics and, in tandem, the modern concept of energy itself (Caffentzis, 2013; Hildyard & Lohmann, 2014; Daggett, 2019; Lohmann, 2021b, 2021d, 2021e). The various kinds of artisans described by Marx in Chapter 14 of volume I of *Capital*, not yet subject to more modern divisions of labor, would simply not have known what to do with the amounts of cheap energy required for a Ford assembly line. In fact, they would have had little use for the novel concept of energy itself, which began to be theorized in its modern sense only in the first half of the 19th century in imperialist northern Europe (Smith & Wise, 1989; Porter, 1994: 141; Daggett, 2019). They would have been puzzled by the idea that a "horse pulling a treadmill and a coal fire heating a lime kiln [a]re in some sense doing the same thing" (Mokyr, 1999), and many would have found their interests threatened by the extraction, energy-conversion and transmission infrastructure required for the commensuration and delivery of such an energy (Pirani, Lohmann and Schwartzman, 2022: 23) and its institution in the world as a new, essentially colonialist nature (Lohmann, 2021d). In addition, the process of modifying prior divisions of labor and inserting machines and abstract energy into some of the divided parts supports a logic of developing still further machinic facsimiles of each partial activity. Under industrial capitalism, many of the divided parts are designed to absorb and respond to theoretically unlimited increases in the application of thermodynamic energy, as well as to absorb and exploit the theoretically unlimited increases in living labor that continue to be needed to be situated 'to the side' as appendages of industrial machines and their powerful, stereotyped, repetitive motions. The industrial machine/thermodynamic energy combination, once entrenched, enabled capital to subject the skills of ever more enclosure-dispossessed workers around the world – whose labour-power could now be more easily bought and concentrated by property owners – to centralized disassembly, reorganization and control, facilitating 'combined labour' on ever more populous factory floors globally (Tinel, 2013; Daston, 2018) and bringing capital into an altered relationship with slavery. The new abstract energy made it possible for many of the 'slow' individual bodily human motions associated with, for example, spinning or weaving – which had historically been entangled and sustained within other social and ecological wholes – to be profitably isolated, made uniform, strengthened, retimed, and repeated trillions of times at unprecedented and indefinitely-augmentable speeds within new manufacturing contexts.

Similar twinned processes occur when a territory's *non*human 'labor' is divided up and altered through the large-scale, more or less monoculture plantations and regiments of workers or slaves that supply so many capitalist processes, enabling each parcel of what becomes quantifiable, abstract 'land' to be assigned a separate, uniform function, again for productive purposes (Wolford, 2021; Ofstehage, 2021). At that point it begins to become possible and logical to try to apply those same indefinitely augmentable quantities of uniform 19th-century energy to an indefinitely expanding mass of agricultural machinery and machinic processes (US Energy Information Administration, 2014) capable of absorbing, controlling – and degrading (Scott, 1998: 15-22) – the vital 'labor powers' of the soil. Today's agribusiness operations continue to strip out certain communally-evolved plant and animal capacities, isolating and assimilating and reorganizing them into machinic patterns featuring widespread, rapid repetition under centralized direction (Magdoff, 2015; GRAIN, 2022). Mineral extraction, in similar fashion, separates out single aspects of geological formations, altering and re-entangling them in networks of mass production whose lifespan is also limited (Corvellec, Hultman et al., 2021). This pattern is continuous and progressive. Repeatedly pushed from 'formal subsumption' toward 'real subsumption,' capital has continually sought, found and extracted fresh, low-cost fragments useful for machine operations deeper within the socio-biological capacities confronting it as nonhuman as well as human nature (Boyd & Prudham, 2017; Moore, 2015; Walker, 2016; Burawoy, 1979). As capital's debt to the past has increased with its excavation of more and more sedimented remains of photosynthetic work in the form of fossil fuels (Dukes, 2003), so too has its debt to the myriad evolved patternings (Kohn, 2013) of living organisms, more and more varied pieces of which it has also continually striven to attach to machines. The elliptical term 'mechanization' is as inadequate for taking account of these myriad ecological reassemblies as it is for understanding the rearrangements of living human labor that mechanization also involves.

Integral to these assemblages are specific logics of degradation, diminishing returns, or fatigue that compel the frontier that constitutes capital (Moore, 2015) to move continually 'outward' (e.g., to deposits of the sedimented work of prehistoric photosynthetic organisms in coal or gold reserves) and 'inward' (e.g. to genes or crystallized human cultural abilities) in compensation (Moore, 2015; Walker, 2016; Boyd & Prudham, 2017). As Deirdre Shauna Lynch (1998: 192) notes, 'Adam Smith's discussions of the alienating effects of the division of labor – of work that consisted in nothing but the repetition of a single simple gesture – anticipated the Victorian factory inspectors' tales of selves "mutilated" by their bodies' occupation' among machines powered by the new 19th-century energy. Marx (1867) often referred in vitalistic or metaphorical terms to the ongoing challenge to industrial capital posed by the progressive debilitation of the organisms of the industrial workers whose 'contentless,' monotonous and exhausting living labor was so essential to keeping its machines running (364-66, 595-99, 455-639). He repeatedly emphasized the way that capital accumulation depended upon – yet simultaneously sapped – living labor's 'vital energy', 'will', 'bodily subjectivity', 'form-giving fire' and 'self-negating capacity', comparing these qualities to the 'blood' on which the 'vampire' of dead or objectified labor feeds to produce surplus. Marx also famously examined the problems connected with the loss of fertility of soils associated with capital's needs for raw material derived from a mechanized or plantation agriculture divorced from urban society (638-39). As later writers have described, this soil debilitation in turn prompted the expansion of bio-mineral (guano, saltpetre and phosphate) and above all petroleum frontiers (Saito, 2017; Clark & Foster, 2012; Angus, 2019; Foster & Magdoff, 1998; Danielewitz, 2019). For capital, whether, when, where and how to enclose commons to annex living labor power and raw material, and whether or when or how long components of commons can be maintained to provide cheap support, rejuvenation and reproduction for 'cyborg' workers (Hildyard & Lohmann, 2014; Haraway, 1991), is a perennial, ticklish issue (Perelman, 2000; Colatrella, 2002; Araghi, 2000; Kelley, 2015 [1990]; Freeman, 2010; Hochschild, 1989; Webber, 2012; Caffentzis & Federici, 2014; Cox & Federici, 1975; Caffentzis, 2012), along with the question of whether, when, where and how to destroy or, alternatively, merely supervise relations among human beings outside the formal workplace. To put the issue in Marxian terms, how far can socially-necessary labor time be reduced in favor of surplus labor-time without the commons relationships that underpin reproduction becoming degraded to the extent that the worker becomes unable to contribute to surplus accumulation? This productivity/fatigue dialectic, moreover, has long been global in scope. For example, when 19th-century capital smuggled the vital activities of native Latin American rubber and cinchona trees out of their original, complex, long-evolved human and nonhuman contexts and brought them, in the form of monoculture plantations, into contact with the abundant cheap, fresh, semi-proletarianized labour power it had helped create in Asia, as well as with increasingly fossil-powered forms of regimentation, simplification, mechanization and violence, it engendered a progression of problematic knock-on effects on humans, tree species, earth systems and capital alike involving degradation, exhaustion, and cascading attempts to compensate for both. This dialectic shows no signs of letting up two centuries later (Cuvi, 2015; Kohn, 2013; Aso, 2018; Tully, 2011; Haraway, Ishikawa et al., 2015).

Post-Marx, a variety of non-vitalistic vocabularies have been developed to try to encompass these various ways that capital continually undermines what gives it life. Notable examples include Jason W. Moore's (2015: 119-120, 226) term 'maxing out' (replacing the problematic 'resource depletion'), which designates a process through which nature, including human nature, can no longer be appropriated in a volume and at a cost that 'sustains accumulation'; Arlie Hochschild's (1989, 2014) descriptions of the contradictory effects of the advancement of 'commodity frontiers' into areas of love and care, and Wolfgang Schivelbush's (1996) and George Caffentzis's (2013) terminologies of fatigue, shock and accident as applied to mechanization. Another vocabulary with great potential for advancing understanding of capital's productivity/degradation dialectic – and one of particular importance for this article – is that of thermodynamics itself. The First Law of Thermodynamics, postulating an energy that could be neither created nor destroyed, came to symbolize capital's exuberant development of the possibilities of commensurating heat, mechanical force, electricity, chemical energy, etc. into an omnibus, interconvertible, abstract, universal 'workforce' (Caffentzis, 2013; Hildyard & Lohmann, 2014; Lohmann, 2021b). From the start, the First Law was paired in a 'contradictory unity' (Harvey, 2014) with the Second Law, which emphasized that the profitable proliferation of energy conversions (Smil, 2017: 26) that cheaply nourishes the tissue of industrial capital is inevitably accompanied at each step by a loss of 'usable' energy. Or, to use the phrasing of the great German physicist Rudolf Clausius, *entropy* tends to increase in a closed system (Cropper, 2004: 93-105).

Inspiring capitalists to try to put the entire universe to work (Caffentzis, 2013), the First Law conceptualized a monolithic 'energy' that was both inexhaustible and interconvertible, and in so doing helped inaugurate a new global capitalist 'nature'. Whatever capital needed to make machines run – mechanical force, heat, electricity, magnetism, light – could be conjured up from any other form of energy that was lying around, given enough ingenuity. In steam engines, heat became mechanical energy on a new scale. In batteries, chemical energy became electricity and vice versa. In turbines, dynamos and windmills, mechanical energy became electricity at thousands of new locations. In electric motors, electricity became mechanical energy. On today's solar farms, the sun's radiation becomes heat or electricity. In light bulbs and laptops, electricity turns into heat and light. This endless convertibility – culminating in the emergence of a distinct 'energy sector' (Hildyard & Lohmann, 2014) – helped create conditions making possible increased donations by workers of their life activities to capitalists to create surplus value. In short, distinctive, sweeping patterns of energy conversion on an ever-growing scale are intrinsic to all forms of industrial capitalism (and, as we shall see, to the digital form of industrial capitalism above all). In an increasingly-entrenched hierarchy expressed in the First Law, each entangled 'little energy' of the commons – cooking fuel collected from common woodlands, oil left underground, undammed streams – is seen as subordinate to an overarching, 19th-century, Big-E abstract Energy (Lohmann & Hildyard, 2014; Baka, 2017; Bonneiul & Fressoz, 2016: 63) that emerged as one of the 'cheaps' on which capital came to rely (Patel & Moore, 2018).

The Second Law interposed a soberer view suggesting that this new, Big-E Energy is better conceptualized as sweeping geographical rearrangements of gradients between low and high entropy (Rovelli, 2016; Prigogine, 1961; Hornborg, 2001). It shows that the more that capital instrumentalizes river flow, fire, wind, coal deposits, magnetism and so forth as being mere aspects of a great pool of abstract energy, the less of the new energy actually becomes available for capital's own use. The more that energy is converted back and forth into different forms (Smil, 2017: 26), the more of it is 'degraded'. In each energy conversion theorized by the First Law, something is lost irretrievably. Writing in 1824, Sadi Carnot, the first genius of thermodynamics, called these conversions 'falls' (*chutes*), pointing to a fertile analogy with waterfalls. Once a sluice gate is opened to let water run downhill to drive a waterwheel, the water can't be induced back uphill to restart the process without expending more energy than has already been released. Similarly, when coal is burned, the resulting heat, ash and carbon dioxide can't be reassembled back into coal without using more energy than the coal generated. With each energy conversion, energy gets dispersed across a greater number of microscopic states. On this view, what capital needs for its machines is not energy as such but these 'falls' in the landscape – differences between low and high entropy. These include gradients between hot and cold in heat engines, between the binding energy of electrons in molecular bonds and the heat generated in chemical reactions, between short-wave solar radiation at around 5760 Kelvin and longer-wave radiation emitted by the earth at 255 K into an outer space standing at a temperature of 2.7 K, and many more. When capital burns oil or runs radiation from the sun through solar panels or industrial biomass plantations, it does not use up energy but rather (to adapt an illuminating metaphor formulated by the quantum physicist Carlo Rovelli [2016]) pulls open various doors – usually violently – through which an entire territory slips more rapidly down those gradients, eroding the gradient itself in the process. Naturally, the sequence and patterning of that door-opening has to suit the operation of capital's conversion devices. Sluice gates are useless if they can't be opened and closed at the right times; coal is useless if heat and oxygen can't be applied, and carbon dioxide vented, in rhythms and places that fit the functioning of machines in controlling, disciplining and increasing the productivity of labour of all kinds. What I have elsewhere called a 'Carnot landscape' (Lohmann, 2021a) tailored to the needs of industrial machines, in other words, will necessarily be different from, say, a landscape in which relationships need to be maintained with 'earth beings' such as mountains, cared for as integral to human identity and place (de la Cadena, 2010). A distinctive kind of hierarchy must be imposed to ensure its construction and maintenance. But this hierarchy will be at least potentially at odds with commons and household practices everywhere in which various forms of energy – wood for cooking, streams for irrigation – are deliberately kept uncommensurated with one another (Baka, 2017).

This does not necessarily imply that more 'entropy doors' are opened in Carnot landscapes than elsewhere. Everywhere, the door-opening process is nothing less than 'what makes the world go round … what causes events to happen in the world, what writes its history' (Rovelli, 2016). The universe's hypothetical prolonged one-way trip toward what 19th-century physicists dramatically called *Wärmetod*, or 'heat death', is, paradoxically, what gives it life – just as capital's energy conversion devices function only when they move toward eliminating the gradients that make them work. But patterns of entropy flow and system boundary-setting are variable. Entropy increases unevenly, at different paces in different places (Reichenbach, 1971: 119, 127). Often the pace is very slow. For example, hydrogen and oxygen molecules can float around peacefully in a bottle for centuries, despite the fact that their combined internal bond energies are greater than that of the water that they could produce. Only when a spark is introduced will they react explosively to dissipate some of that internal energy into heat, forming the higher-entropy H_2O. Similarly, low-entropy oil that is left underground won't react with air to form heat and carbon dioxide for millennia unless it is deliberately unearthed and burned, opening channels that abruptly change it from a pool of low entropy into a larger expanse of residual heat and other 'wastes' that capital is unable to recycle while still remaining capital. Similarly, earthly territories of flowing water that are so often the focus of communal care across the world are in a state of higher entropy than the solar particles that, combined with gravity and other factors, indirectly give rise to them. Indeed, they owe their continuing life to entropic processes that, according to thermodynamics, drive all closed systems (and perhaps even the universe itself) toward stasis. All the same, they constitute basins whose local rate of entropy increase can remain relatively low for millions of years, until capital suddenly boosts that rate by seizing control and converting the kinetic energy of those flowing waters into electricity via hydroelectric dams, again leaving behind a landscape of waste. In general, the more intensively capital converts energy from one form to another, the higher the entropy of the system. And if that system is closed, the closer that entropy changes come to halting altogether.

This dynamic is reinforced by the fact that capital typically structures its unprecedented entropy increases in chains. Before hydroelectric dams and turbines can go about their entropy-increasing business, entropy-increasing concrete and steel manufacture has to take place. Entropy-increasing wind turbines can't be built without previous entropy-increasing steel manufacture in China and balsa extraction in Ecuador (Bravo, Mendoza et al., 2021). Rising rates of entropy increase associated with the movement of electrons in millions of electric cars in the global North stem not only from the prior construction of dams, wind farms and other energy-conversion devices, but also from new waves of entropic lithium and copper extraction in Chile, cobalt and nickel extraction in Congo and Indonesia and so forth (Bhutada, 2022). These chains can only multiply overall entropy increases. In coal-fired generating plants, 60 per cent or more of the fuel's chemical energy is lost as waste heat. An additional percentage of the electrical energy generated is then dissipated into heat in transit to – for example – those high-frequency trading server farms or cryptocurrency mines stuffed with computer processors that need built-in cooling systems to dispel their own waste heat. Even the most up-to-date efficient light fixtures lose at least 20 per cent of the electrical energy feeding them. Their light is then partly downgraded again into heat on contact with, say, a billboard on an empty street at night (Smil, 2017: 26).

Defying these trends in chosen zones where gradients between low and high entropy need to be maintained – in capital's case, in order to keep chains of labour-exploiting machines running – requires 'exporting' high entropy into surrounding regions. Industrial capital's geography – collections of Carnot landscapes – is necessarily one in which boundary demarcation is constantly going on so that the environments of the increasing mass of energy conversion engines can be maintained in a nonequilibrium, dissipative steady state in which low entropy is constantly 'coming in' and high entropy 'going out' (Kleidon, 2016; Virgo & Harvey, 2007; Schneider & Sagan, 2005; Schrödinger, 1944). That is, if industrial machines, somewhat like living beings (Davies, 1998) constantly need systematic 'activation' (Lambert, 1998) of successive metastable zones of low entropy, they also need accelerated increases of entropy there and elsewhere. Hierarchical Carnot landscapes featuring multiplying First Law conversion engines of large size are also landscapes of increasing Second Law 'waste'. These, of course, are also hierarchically organized, in the form of relationships between energy beneficiaries and 'sacrifice zones' (Svampa, 2015) of extraction and pollution. Both changes need to occur 'outside' the machines themselves, as ordinarily conceptualized, involving wholesale shifts in the sites of energy dissipation. It is the resulting 'entropy balance' that 'sets the limit to the power of the engine' (Kleidon, 2016). Accordingly, if entropy is about territory (in a more than spatial sense), it is also about one territory's relations with another. In the vocabulary of physics, the 'extent to which the boundary is flexible in exporting entropy is a critical factor in calculating how far the system can evolve' (Kleidon, 2010), and for what period of time it can evolve, without collapsing into thermal equilibrium. In a more sociological vocabulary, 'unequal exchange in the world system is what reproduces machines, and machines are what reproduce unequal exchange' (Hornborg, 2001: 44). Colonial projects are essential to restoring flattened-out entropy slopes.

The nonequilibrium (and far-from-equilibrium) thermodynamics touched on in the last paragraph (Ornes, 2017; Chatterjee & Innachione, 2019; Davies, 1998, 2019; Kleidon, 2016; Rosen, 2012: 223 ff.) – an exciting field in contemporary physics and biology pushing new understandings of the Second Law's operations – helps in grasping other dimensions of degradation and colonialism as well, particularly those relating to time. Entropy has long appeared to be the only concept available to physics that makes sense of the idea of an arrow of time (Halliwell et al., 1994; Stanford, 2021). In good 'apolitical' fashion, 19th-century thermodynamicists like Clausius, by putting a figurative border around the entire universe, universalized this arrow and the 'heat death' toward which it pointed. To do so was entirely justified, but it did tend to obscure the unevenness of *rates* of entropy increase within various earthly borders (Mayumi, 2001; Reichenbach, 1971), and how they change under capitalism. Contemporary nonequilibrium thermodynamics may help put this unevenness back under the spotlight and 'provincialize' (Chakrabarty, 2008 [2000]: 3-97), without refuting, the 'European' sense of a universal timeline culminating in heat death. From an unexpected direction, it may enrich discussion among commoners who are unimpressed with the First Law 'liberation' of abstract energy that is attributed to a few northern European intellectuals' supposedly disinterested discoveries, and who are uninclined to take overseriously the burdens of universal heat death, a universal, singular arrow of time, or the associated 'categorical imperative' coined by the Nobel chemist Wilhelm Ostwald (1912: 85) that one should "not waste energy, but convert it into its most useful form" (see also Caffentzis, 2013). To put it the other way around, the same commoners who decline to elevate Wilhelm's abstract 'efficiency' into a universal virtue are likely to be those with a lively understanding of – for example – the "over twenty different kinds of time" with which an Indigenous practitioner of shifting cultivation in India may operate in the course of paying proper democratic attention to "soils, seed, seasons, rituals, fast, feast, rest, work, domestic and communal space" (Viswanathan, 2007: 345; see also Smith, 2007; de Sousa Santos, 2007; Rivera Cusicanqui, 2012; Lenkersdorf, 2008; Estes, 2019). Communities with a livelihood interest in keeping oil in the soil in the Niger Delta or the Ecuadorian Amazon (Temper, Yanez et al., 2013) will have reason to contest the imperative to convert it into heat and the "more useful form" of mechanical energy. A community with a livelihood interest in keeping unconverted in a local flowing stream what physicists call kinetic energy (Global Nonviolent Action Database, 2010) will not necessarily be impressed with the injunction to convert as much of it as possible into cheap electromagnetism in order to avoid 'wasting' it without economic benefit. Keeping the oil in the soil, the 'potential electricity' in the stream, the wood in the stove and the forest, and so on, goes hand in hand with respect both for what Andean Indigenous communities refer to as *territorios* and for multiple times. That respect consitutes inherent resistance to a 19th-century European energy hierarchy that tends to 'minoritize' (Segato, 2019), render subaltern, or suppress various struggles, proposals and aspirations widespread among the global majority (Chakrabarty, 2008 [2000]). That respect also militates against the elevation of clock, factory or railroad time (Thompson, 1967; Glennie & Thrift, 2009; Viswanathan, 2007) into a 'universal' background encompassing all other times. In so doing, it also puts in its place what Charles W. Mills (2014) calls the 'sanitized and idealized White time' – steeped in the boundary politics that defines slavery, genocide, aboriginal expropriation and colonial rule over people of color – that is the currency of mainstream historiography (see also Trouillot, 2015 [1985]). Yet paradoxically, it is also respect for multiple times that helps protect sources of labor power (Caffentzis, 2013) and of 'cheap natures' (Moore, 2015) for the industrial capitalism that depends on them. As Caffentzis (2012) notes, such commons norms are "not logically antagonistic to capitalism. On the contrary, a necessary condition for the existence of capitalism is the presence of certain kinds of commons."

In short, the geographic images that tend to be associated with the First and Second Laws persist in a state of mutual tension reflecting the central contradictions of capital accumulation. Despite the cautions of physicists (Bridgman, 1943: 115; Feynman, 2010: 4.1), the First Law encourages capital to take an abstracted or fetishized view of energy as a unitary 'thing' independent of space and time, a singular resource extractable from a variety of sources and then 'used up' at various points of an essentially invariant landscape to make more and faster production possible. On this view, energy can be 'depleted' and 'renewed' (or not), in principle for the benefit of all human beings, who are conceived as autonomous entities existing independently of place and sharing a commmon interest in abstract efficiency. This is the geographic perspective of (for example) the International Energy Agency and its statistics about energy 'consumption' (IEA, 2021). In contrast, the Second Law points to a different aspect of energy – Carnot landscapes. Carnot geography reveals – both to capital and to capital's antagonists – industrial capital's intrinsically colonialist, racist requirement for the constant reorganization of new entropy borders and the associated patterns of 'maxing out' various capacities of human and more-than-human natures. From this perspective, what are called 'Ministers of Energy' are in reality 'Ministers of Entropy Flow'. Their brief is to help wrench open their territories' entropy doors and, if possible, keep their territories and others in such a state that they can continue to be wrenched open. On this view, the ‘energy’ that today’s policymaking classes chatter about is more accurately described as a continuing, forcible territorial and interterritorial political reorganization in the service of the governance of capitalist labor. A First Law map is unlikely by itself to be able to depict such relationship and border changes. Typical treatments of ‘energy geography’, insofar as they remain unreflective about the political origins of modern energy (e.g., Pasqualetti, 2011; Huber, 2015; Calvert, 2016), leave out what is arguably of most geographical significance about energy: the evolution of these Carnot landscapes in line with the imperatives of capital accumulation.

3. AI in the weave

Today these observations about the human- and world-ecological structure and evolution of post-18th-century industrialization need to be expanded and extended to cover the development of the new industrial machine networks that make up so-called artificial intelligence. As outlined above, one strategy of capital’s struggle against labor that became possible and necessary in the 19th century was to develop the industrial machine/abstract energy conjunction in ways that altered and ‘automated’ (or perhaps, better, considering the discussion in the above section, ‘heteromated’) typically ‘adult’ skills such as weaving, steelmaking, papermaking, farming and so forth. As I have argued elsewhere (Lohmann 2019, 2020), for 21st-century capital, it has become possible and necessary to contemplate ‘automating’ (or perhaps, better, ‘heteromating’ or even ‘niggermating’) a deeper, more fundamental layer of skills that humans tend to acquire at a much earlier age through material interactions simultaneously with other humans and with the more-than-human world (Davidson, 2001; Barad, 2006; Rouse, 2004). These skills include recognizing, interpreting, translating, wayfinding (Ingold, 2000: 219-42), learning, remembering, calculating, inferring, verifying and many others. Getting the convolutional neural networks and other machine skeins that are supposed to automate all these skills up and running requires continuing ‘resourcification’ (Corvellec, Hultman et. al., 2021) – not only of geological and biological formations, as with earlier industrial revolutions, but also, as Nick Couldry and Ulysses Mejias (2021) emphasize, of the trillions of everyday social interactions that are turned into big data via billions of sensors and digitization devices grafted onto living subjects through smartphones, personal computers and other devices. As part of the process, it can be no surprise that these data and their creators become conceptualized as unvalued, unused ‘open resources’ or even ‘exhaust’ (a new version of ‘waste’, to revert to a colonial-era term for commons) ripe for colonial extraction and processing.

In many ways, the skills of recognizing, translating, calculating, remembering and so forth now supposedly being mechanized – unlike epoch-specific, more or less ‘adult’ abilities like weaving and papermaking that are conventionally identified with productive labor skills – can be seen as grounding the whole of living labor, child and adult (Lohmann, 2020; Pasquinelli, 2019). To put it another way, all living labor of whatever kind involves individual workers more or less constantly interpreting, calculating, recognizing, identifying, thinking, remembering, learning, wanting, understanding, inferring, searching, communicating and cooperating. Despite the inextinguishable, self-interested proclivity of elites, including those on the left, to set apart their own brand of work as distinctively ‘intellectual,’ ‘mental,’ ‘symbolic’ or ‘cognitive’, interpretation and cognition in fact permeates all labor processes down to the inculcated trajectories of the hammer of the most brutalized ‘manual’ line worker. Such workers, like all others, need to learn and develop motions embedded in cognitive contexts (Sudnow, 1979) and to communicate, coordinate, cooperate and engage with supervisors and fellow workers in ways grounded in what Julia Elyachar (2010: 453) calls “phatic labor” (everyday interaction including questions, pointing, jokes, gossip, teasing, play, gestures of fun and love and other forms of more or less disinterested sociality that produce "communicative channels that can potentially transmit not only language but also all kinds of semiotic meaning and economic value") or what David Graeber (2011: p. 98) calls "baseline communism" (the quasi-egalitarianism structurally inherent in the ability to converse that "founds the possibility of larger social relations") (see also Caffentzis, 2012). Both presuppose and build on interpretive or cognitive skills inculcated in years of material interactions with parents, childhood companions and a 'plurality of creatures' all visibly responding to 'shared external promptings' (Davidson, 2004: 143) in the physical world (Davidson, 2001; Sellars, 1997 [1956]; Wittgenstein, 1953). These material interactions share a structure not generally found in the genesis and development of machines. (For a speculative treatment of the hypothesis that they someday could share this structure, see Chiang, 2010; see also Collins, 2018: 154 ff.; Davidson, 2004: 77-99; Davidson, 2001: 95-105.)

Capital's ambitious attempts to adapt AI to automate some or all of these core aspects of human labor (Pasquinelli & Joler, 2021) – or just to be able to issue credible threats to replace them in whole or in part – constitute new weapons in its class struggle against its workers. On an immediate, practical, granular level, increased partial or piecemeal automation of the basic human skills of interpretation that most people acquire during childhood constitutes, for many sectors of capital, a welcome step forward in separating the means of production (and distribution [Pfeiffer, 2022]) from workers and concentrating them in private hands – essentially the same process that received such a boost during 19th-century industrialization. For example, self-driving vehicles able to predict cheaply and with enough accuracy and speed what human drivers would do if confronted by a particular view of a crosswalk or a bicyclist could put some humans out of work, saving wage costs and forestalling class confrontations as well as taking away one impediment to the rapid circulation of capital. Translation engines have already displaced huge amounts of interpretation work by making accurate, super-fast predictions of how human translators would react to large volumes of symbol strings in specified contexts. Machines able to predict how each of millions of individual consumers would act if their attention were structured in certain ways are also slashing 'consumption labor' (Weinbaum & Bridges, 1976; Huws, 2013) and even the human labor of shopping and marketing (Agrawal, Gans et al., 2019; Tapscott & Tapscott, 2016), streamlining turnover. Sentiment-detecting machines predict millions of individuals' future emotional reactions to hypothetical situations on the basis of thousands of data points from multiple individuals' distant and immediate pasts, helping to reshape and refine the 'audience commodity' sold to advertisers that Dallas Smythe identified many decades ago as one 'product' of information capitalism (Smythe, 2006 [1981]; Fuchs, 2012). 'Industrie 4.0' algorithms predict what human workers would do on assembly lines, thereby shifting the roles of the human labor force in factories (Pfeiffer, 2016). Optical character recognition devices, by predicting how literate human subjects would react to certain orthographic shapes, have been upending human sorting and reading work for decades. High-frequency trading machines predict how human traders would react to numbers as prices, eliminating many human job descriptions in finance. Automated farming or nature conservation contraptions are striving to predict the different ways skilled humans would respond to different species of insects and plants and their ever-changing antics. Search engines are constantly refining their abilities to help predict which symbol strings different classes of human will and will not find relevant to their concerns. Chemical and genetic recognition machines work swiftly to predict the economic possibilities of various compounds and sequences that might otherwise need laboratories full of human workers to assess. Similarly, cryptocurrencies and 'smart contracts' aim broadly at 'objectifying' and centralizing the 'labor of trust' (Lohmann, 2019a) into machines administered by platform owners. The energy-intensive machine/human networks known as 'the Cloud' are meanwhile designed to be able to handle many such discrete processes of 'automation' and centralization at once. The importance for capital of all these acts of simulated interpretation lies largely in the fact that they can be carried out at a velocity and in a volume of which even vast armies of humans would be incapable by themselves, via human-maintained self-adjusting deep learning algorithms, processors operating at unprecedented speeds, and immense statistical samples produced by billions of cyborgs fusing humans, smartphones, computers, digital cameras, optical fibre lines, satellites and hydroelectric dams, engaged around the clock in digitizing sensory, linguistic and other types of human experience or negotiation for input to proprietary mechanical processes.

As in the 19th century, a still larger, almost subliminal agenda often lurks behind these varied, piecemeal, tactical moves by capital against labor. Nineteenth-century industrial mechanizations undertaken in particular sectors and locations – as well as the move toward steam power as a generalized support for industrial production across the board that was heralded by James Watt's and Matthew Boulton's firm founded in 1775 – were often accompanied by lingering hopes for an industrial perpetual motion machine that could somehow defy the entropy increases theorized by the emerging Second Law of Thermodynamics. At the same time, piecemeal mechanizations were also often animated by fantasies of relocating *all* of laborers' 'intelligence' to machines concentrated in the hands of capital (Schaffer, 1994, 1999; Marx & Engels, 1994 [1861-3]: 26). Roughly speaking, the dream was for capital to be able to accumulate without having to bother its figurative head about either coal supplies or the vagaries of shiftless workers. Today, wishful references to perpetual motion have largely fallen by the wayside, reappearing only occasionally in the ravings of cranks or in obvious oxymorons like 'renewable energy' or 'circular economy'. But the (unfulfillable) fantasy is still going strong of someday being able to dispense with human living labor across the board (McNally, 2003; Caffentzis, 2013; Dyer-Witheford, 2019; Bastani, 2019), thus bypassing entirely the need for labor negotiations, union-busting, pay increases, reproduction of human workers and other inconveniences. The vision of 'deep mechanization' holds a special charm for libertarians eager to rid themselves of any and all human 'intermediation' by the state, by bankers, and by 'parasitic' or 'inefficient' classes of lawyers, judges, accountants, police and other bothersome gatekeepers who currently hold sway over the interpretation and enforcement of contracts and other norms (Lohmann, 2019a). Some nature conservationists, in addition, envisage grafting AI onto other-than-human beings such as forests so that they could manage themselves in perpetuity without any need for human supervision at all (Lohmann, 2019a). For many proponents of today's 'automation discourse' (Benanev, 2019) on both right and left, the point of what is known as Artificial *General* Intelligence (AGI) is that it could one day become a stand-in for generic living human labor *as such*. Thanks to AI, that is, it has become possible once again for capital and its admirers to dream, as they did in the days of David Ricardo (1951–1973, vol. 11: 399-400), of the "complete dissociation of living labour … from the production process" (Ramtin, 1991: 58, cited in Steinhoff, 2021). In the more delirious versions of this scenario, capitalists themselves get replaced by automatic mechanisms, freeing accumulation from human beings entirely (Land, 2018).

As in the 19th century, however, reality is less than obliging. Mechanizing fragments of the living labor of recognizing, perceiving, calculating, wayfinding and so forth in one place turns out to require recruiting even more living labor elsewhere if capital is to maintain a satisfactory overall rate of profit. As always, "dead labor demands fresh living labor" cheaply reproduced and replenished in the commons in order to generate value (Kirsch & Mitchell, 2004: 696; see also Antunes, 2013: 97). Whether inside AI-enabled 'Industrie 4.0' production lines (Pfeiffer, 2016, 2018) or along 21st-century capital's countless supply, distribution and information chains, ceaseless flows of living work remain essential in animating 'dead' labor. As in the 19th century, what Gray and Suri (2019: 1-63) somewhat misleadingly call 'automation's last mile' is one that can never be traversed.

The contradictions can be explored from diverse but complementary and overlapping perspectives. The following section puts forward five such perspectives suggesting why AI is unlikely in the foreseeable future to be of much help in fulfilling capital's recurring, contradictory dream of accumulating value without relying on living labor.

4. Why AI is not a substitute for living labor and does not create value for capital: five perspectives

Why is AI not a substitute for living labor? Why is it not creating capitalist value? The following arguments may help provide materials for an answer.

AI's acts are not holistic in the ways required for capital accumulation

If 19th-century weaving machines do not in fact weave nor spinning machines spin, neither do 21st-century recognition machines recognize, translation machines translate, nor wayfinding machines find their way through a more-than-human world. Digital computers cannot even calculate (Wittgenstein, 1978: §61, 1980: §1096; Shanker, 1998: 2, 26-27). Computers, electronic calculators and automatic camera focus device alike all require constant living cognitive work by their operators in order to function properly moment to moment and day to day (I am leaving aside the living human work needed in the supply chains that feed them). As Harry Collins (1990: 11-71) demonstrated long ago, computers cannot actually (for example) do arithmetic, but merely contribute speed and mechanical power to certain steps in the middle of arithmetic practices, between the human work that is required both "on the input side" (including broad knowledge of how and why society needs things to be measured and how machines need to be treated and operated) and "on the output side" (including recognizing machine outputs for what they are and checking and repairing the results) (64) – that is, "all the arithmetical acts that come logically prior to and logically after the mechanical part" (53). Thus a machine trusted to do arithmetic would need to be able to do more than output something a human might be able to recognize as '175.26 centimetres' after it is fed a hitherto-unseen question about metric conversions. It would also need to know, for example, "how exact to make a calculation, … when to give a rough answer even if a more exact one is available, … whether, and how, to make a rough calculation when it is not possible to make an exact one even if an exact one would be better … and when a calculator and pencil and paper are counted as doing the same thing and when they are not" (Collins 1990: 55-56; see also Wittgenstein, 1953, 1978, 1980; Shanker, 1998: 1-10; Lave, 1988; Lave & Wenger, 1991; Bloor, 1991 [1976]; Verran, 2001).

But if computers cannot (yet) make calculations, neither are they currently able to replicate any other 'elementary' labor skill such as recognizing, interpreting, wayfinding, remembering, verifying, foreseeing, inferring, finding workarounds and so forth. With the help of large quantities of energy, fast processors, neural nets, and big data, AI's abilities to carry out some 'middle parts' of these social practices have become enormously hypertrophied, enabling computers to contribute to breathtaking feats of rapid statistical prediction at high environmental cost. But to function for capital accumulation, these monotonic electromechanical behaviors, prone to difficult-to-anticipate, sometimes catastrophic mismatches with economic processes, must be sandwiched and made whole by large amounts of living human labor whose skills originate in slow years of varied experience (Pfeiffer, 2016, 2018). Like calculation, other fundamental skills of living labor are developed holistically, together with each other and prior to or alongside other labor skills. They presuppose a history of causal interaction with many objects in the presence of at least one teacher or other commentator or communicator interaction with whom can foster the ability to contrast "what is believed and what is the case" (Davidson, 2004: 105) – namely, to have beliefs about beliefs or about the concept of a reality independent of beliefs. Such labor skills cannot be acquired one by one because each requires an "enormous supporting repertoire" (Davidson, 2004:89) including the ability to give reasons for what one does that call on a very large number of beliefs and desires. As Donald Davidson (2004: 90) puts it, "to have even one thought – one belief or desire – a computer would have to have a very great many other thoughts and desires." Or to adopt the earlier, equally Wittgensteinian terminology of Wilfrid Sellars (1997 [1956]: 76): "in characterizing an episode or a state as that of *knowing,* we are not giving an empirical description of that episode or state; we are placing it in the logical space of reasons, of justifying and being able to justify what one says". The general point had been made still earlier by the developmental psychologist Lev Vygotsky when he noted, for example, that "the concept '9' involves a number of judgments which are not in the nine on the playing card; '9' is not divisible by even numbers, is divisible by 3, is 32, and the square root of 81; we connect '9' with the series of whole numbers, etc. … psychologically speaking, the process of concept formation resides in the discovery of the connections of the given object with a number of others … a mature concept involves the whole totality of its relations, its place in the world, so to speak" (quoted in Reigeluth & Castelle, 2021: 99-100).

Reproducing a history that could provide command of these relations has not yet been seriously attempted in AI development. As a result, AI is as yet unable to replicate even the ability to recognize a crosswalk, a skill involved in wayfinding and delivery driving. This is because recognizing a crosswalk implies being trusted to know or feel literally thousands of diverse other things, many of which were learned in childhood through bumping into and manipulating objects in the presence of other humans who observed and corrected the child's verbal and other reactions: that a crosswalk is not an arrangement of pixels with certain statistical regularities, but an object occupying a region of three-dimensional space that persists over time even when it is not seen, and can be stepped on or obscured (Gibson, 1979; Shanahan, Crosby et al., 2021); that the activation of a good AI crosswalk-distinguishing circuit is evidence for the presence of such an object and justification for saying that one is present; that other objects are likely to exist in the vicinity that are correctly called 'streets' and 'motor vehicles'; that pedestrians are physical objects and also persons that can be examined, prodded and talked to that moreover have certain habits and inclinations; that a certain color of paint is used to make a crosswalk; that white is a color; that colors are multiple; that paint is a liquid; that there is such a thing as vision; that inertia and friction come into play between vehicle and street; that streets are usually longer than a car; that you can't detour around a crosswalk by driving over the sidewalk; that it would feel bad to be hit by a car; and, of course, that although stripes in the landscape might turn out to be objects relevant to navigation, they might also be pranksters' graffiti or attributes of a passing zebra. A self-driving vehicle that can recognize a crosswalk for what it is must be capable of being surprised if a crosswalk suddenly disappears in front of its camera, its brake pedal turns out to accelerate the car, or the laws of physics are suddenly suspended along Mountain View Drive. It must have a large body of usually unarticulated expectations that can nevertheless be thwarted (Dennett, 1984; Garfinkel, 1967; Davidson, 2001: 104). Hence, in part, the difficulties of producing self-driving vehicles capable of simulating acts of wayfinding among environments and populations not carefully prepared for them beforehand (Ensmenger, 2018b). Similarly, one reason why the decisive triumphs of chess or go engines such as Stockfish or AlphaZero over their human opponents have failed to diminish human interest in playing these games is simply that these machines cannot (yet) show that they know what chess or go are any more than a power loom can demonstrate that it knows what a weaver is. Nor can they conceptualize what a game is, what play is, what a rule is, or what a right or wrong move is; nor can they be said to have a desire to play or win insofar as having one desire presupposes having many others that they do not possess (Davidson, 2004: 89).

Most of this has always been well-understood by AI's most sophisticated and ambitious practitioners (Liu, 2021), starting with the great machine learning advocate John McCarthy (1958) and colleagues in the 1950s. As the prominent AI researchers Ronald J. Brachman and Hector J. Levesque (2022) have recently summed it up, however impressive the performance of separate AI systems like AlphaGo, Google Translate or Siri may be, they remain unintegrated with each other or with common sense. They are "like small islands of high achievement in a large sea of possible behaviors." No one in the AI community knows, state Brachman and Levesque, "how to get a system to behave in a reasonable way outside these localized areas of expertise." To borrow the words of the veteran researcher into human-computer interactions Lucy A. Suchman (2006: 20), "there is (still) no evidence for the achievement of conversation between humans and machines in the strong sense that we know it to go on between humans." This predicament is often discussed as if 'solutions' will some day be forthcoming. Various of its aspects are often referred to as, for example 'the problem of common sense' (McCarthy, 1958; Winograd, 1972; Toews, 2021; Brachman & Levesque, 2022), 'the frame problem' (McCarthy & Hayes 1969; Minsky, 1975; Dennett, 1984; Shanahan, 1997), or 'the problem of background knowledge.' And many AI professionals have shown remarkable diligence in trying to find such solutions. Some double down on the existing projects of statistical machine learning – for automated translation or advertisement placement, for example – that have enjoyed such a boom in the last decade or two, hoping that the results will some day add up to a simulacrum of common sense. Others, more impressed with the holistic nature of understanding, recur to earlier attempts to transfer representations of human knowledge to computers, without, nevertheless, representing their semantic aspects (Davidson, 2004: 91). One example is Douglas Lenat's ill-fated (if fairly low-energy) 38-year-old Cyc project for making 'machine-visible' the totality of implicit commonsense human knowledge. The project is now running at over 25 million propositions, many on the order of "if someone dies, they stay dead" or "emeralds do not suddenly change color from green to blue under normal conditions" (Lenat, 2019; Wikipedia, n.d.; Metz, 2016). Still other researchers, however, have become convinced of the need for a complete change in direction in AI research, including 'deep learning' *eminences grises* such as Geoffrey Hinton (Axios, 2018) and Judea Pearl (2018). What is not in dispute is that what might appear on the surface to be steps toward the complete 'automation' of basic living labor skills such as recognizing, perceiving, wayfinding, calculating, translating, remembering, inferring and so forth turn out, on close examination, to be nothing of the kind, and that lack of holism is one name for this reality.

AI claims to the status of living labor are based on the fallacious notion of a self-interpreting rule

An alternative way of putting the point is to expand on the idea of making a mistake, or of not following a rule correctly, which both belong precisely to Sellars' (1997 [1956]) 'logical space of reasons' (see also Shanker, 1997). Capital needs its workers to do what it tells them. But obedience always implies the possibility of disobedience. Lay down any rule for the worker and the worker can find a way to subvert it by taking the rule too literally or failing to provide the 'supplements' or improvisation that any rule needs in order to be effective. If the capitalist has in mind a right way of doing things, there will also always be a wrong way that equally 'follows the rule' (Wittgenstein, 1953; Collins, 1985). Rules are always reinterpretable; that is their nature. And many of the reinterpretations will be a surprise. This is what grounds the old labor movement tactic of 'working to rule' (Collins, 1990: 83, 90 117). In a never-ending dance, protesting workers slyly reinterpret the rules that capitalists formulate in a way that they actually sabotage production instead of increasing it, indirectly schooling business in the fact that 'efficiency' cannot be achieved mechanically; frustrated capitalists for whom this lesson is most unwelcome then angrily reinterpret the reinterpretations. Energy-intensive mechanization and ever-expanding global energy infrastructure can be seen as part of capital's perennial efforts to call a halt to this dance once and for all by eliminating the possibility of workers' 'wrong' interpretations at the same time they ensure faster, higher-volume, cheaper, more standardized production and circulation of commodities. The underlying fantasy might be phrased as one of automation making capital's rules unreinterpretable, in other words of machines confronting the world on capital's behalf without the participation of human workers. For capital, one appeal of holding private property rights in industrial or digital machines has always been that they seemingly cannot make mistakes nor perform 'incorrect' actions in the way that any human workers that they 'replace' are prone to do. In particular, they seemingly cannot 'disobey' their owners in the way that human workers do, and thus slow down or interfere with production. Unfortunately for capital, however, a machine that cannot disobey – or that supposedly removes interpretation from rules or makes rules self-interpreting, as today's AI-enabled 'smart contracts' are often presented as doing (Lohmann, 2019b) – also cannot obey, much less throw creativity into 'rescuing' a rule whose 'normal' interpretation turns out in new circumstances to be a fetter on accumulation. If such a machine cannot perform incorrectly, it also cannot perform correctly. If it cannot go on strike, it also cannot be reasoned with to modify its behavior, nor rescue capital's routines from themselves. Indeed, it cannot yet be said even to have concepts to reason *with* (Davidson, 2004, 2001; Vygotsky, 1997 [1930]). Thus an AI 'deviation' and a human 'mistake' might both be instantiated in an identical piece of behavior, but the context and means of following up will differ. For instance, as Sy Taffel (2019: 6) notes, automated systems are unlikely to be able to explain their deviations, while humans are "quite good at knowing where, when and why human errors are likely to occur", which is part of knowing what a mistake *is*. To take another example, whereas a human teacher of languages to non-native speakers often intervenes even when a student's answer is formally 'correct' out of a sense that it was not given for the right reasons, or that the student, if probed, would not be able to 'go on' (Wittgenstein, 1953), instruction by (and of) AI tends to rest with the maximization of the number of formally 'correct' answers of a narrowly uniform type.

This narrowness is not relieved in any way by backpropagation, hierarchical processing, convolutional networks (Alpaydin, 2016), generative adversarial networks, synthetic data, or other ways that increase the number of repetitions of the uniformly-structured acts involved. For example, a classifying machine may be trained via a data set compiled through 100,000 momentary acts of human labeling or tagging skill, each of which is in turn grounded in years of the labelers' or taggers' childhood upbringing among peers interacting in complex ways with one another and the physical world (Davidson, 2001). It may then be brought to even higher proficiency via a much larger data set compiled through tens of millions of further acts of faux 'classification' performed by the 'trained' machine itself. At no point do such procedures exit from dependence on repetition of simple 'matching' unconnected to larger repertoires of social practice. That is, at no point can they ascend to Sellars' 'logical space of reasons', any more than an account of an event in a newspaper can be verified by buying more copies of the same newspaper (Wittgenstein, 1953: §85, §198, §454-455). The machine involved becomes more 'trustworthy' in the restricted sense that its 'classifications' can be expected to reflect more and more accurate predictions of the particular symbol strings a human might utter following the isolated phoneme sequence, 'What is this?' It can become better and better at assisting humans to find new statistical regularities, some of them startling. But it does not thereby take any steps toward becoming the living labor required for capital accumulation, with its holistic, complex attributes of trustworthiness-cum-possible-sneakiness.

There is nothing mysterious about this inability of today's machines either to follow or to flout rules. It is rooted in an absence of a history of learning from causal interactions with objects within a community of sentient individuals visibly reacting to the same objects and to one another. That is a prerequisite not only for the concept of making mistakes but also for the concepts of truth or objectivity or indeed for any thoughts about an external world (Davidson, 2001, 2004: 4-12;

Shanker, 1998). Such concepts cannot be built simply by exercise of a capacity to discriminate among different objects or processes.

AI cannot cope with cause and effect as living workers do

Current AI's lack of the concepts of objects or of the possibility of making mistakes is intimately connected with its relative helplessness with respect to cause and effect. In the words of venture capitalist Rob Toews (2021), while AI "excels at identifying subtle patterns and associations in data," it remains at a loss in "understanding the causal mechanisms – the real-world dynamics – that underlie those patterns". And without a concept of cause, it is hard to see how AI could function as living labor, to produce capitalist value within a community of fellow cooperating, disputing living laborers. As Davidson (2001: 52) notes, the "fact that states of mind, including what is meant by a speaker, are identified by causal relations with external objects and events is essential to the possibility of communication, and it makes one mind accessible in principle to another." To assess the possibilities of gleaning surplus from AI, capital would need to be able not only to read AI printouts or observe AI discriminating among different inputs, but also to see shared objects as causing AI responses and understand those responses as conditioned by a history of engagement both with them and with the rest of human society.

This is why a Turing test (Turing, 1950) that would convince capital of the profitability of recruiting an AI as living labor would have to do more than just show that an AI hidden behind a screen could convincingly hold up its end of a teletyped conversation for a few minutes. The AI would also have to be "brought into the open so that its causal connections with the rest of the world as well as with the interrogator can be observed by the interrogator" (Davidson, 2004: 84) for some indeterminate but substantial length of time. That implies bodily, ecological interaction. As Davidson (86) puts it, the "physical realization of a program" does make a difference "to its mental powers". Alan Turing and his equally Cartesian successors took for granted a "fairly sharp line between the physical and the intellectual capacities of man" (Turing, 1950: 434). But "there is no such line" (Davidson, 2004: 84). Canonical Turing tests actually "*prevent* the interrogator from obtaining the information they need concerning the semantic connections beween the AI's output and the world" (82, emphasis added) insofar as they assume incorrectly these connections are 'contained' in the output strings.

In the case of unseen human applicants for laboring positions, by contrast, capital does not need to carry out such sustained bodily observations. It can safely assume that prospective workers' dispositions to give appropriate responses to symbol strings "were acquired in the usual way … by past causal intercourse with things and circumstances of the sort to which the person is now disposed to respond" (Davidson, 2004: 85) – that, for example, a person who holds that 'is a crosswalk' is true of crosswalks came by that disposition through physical interaction with and social experience of crosswalks and the norms surrounding them and the language used in their presence. Because that assumption is unwarranted in the case of AI, there is no reason to suppose that an AI's 'crosswalk' means crosswalk, or indeed that "it means anything at all" (ibid.; see also Putnam, 1975).

The point can be amplified by stressing that in humans, "recognition and expectation are of a piece" (Hacking, 1995: 361). Children acquire the concepts that they later use as living workers to amass surplus for capital not by first learning to distinguish between, say, crosswalks and zebras, and only then learning the causal relationships that surround these objects. Nor do they first discover the causal relationships surrounding various individual zebras and crosswalks and only then start distinguishing them as separate classes. Rather, "guessing at causes goes hand in hand with increasingly precise definition … cause, classification and intervention are of a piece." Lacking this structure and history, AI behavior must constantly be supplemented by the actions of living workers in order to function for capital.

This embeddedness in living labor and its contexts of causal interaction with the physical world is merely a special case of the general need for capital's machines to be embedded in the web of life as a whole (Moore, 2015). Much as 19th-century Manchester textile machines nestled figuratively within a dynamic matrix of uprooted commoners and slaves and their abilities to communicate and intervene physically in nature (together with vast monoculture plantations undergoing biotic exhaustion, collapsing coal caverns, and the beginnings of a warming atmosphere), so too AI is located inside networks of evolving, all-too-human and equally degradable iPhone and computer users as well as those same plantations, coal caverns, air currents and other aspects of a deteriorating life-web. For capital and capital's opponents alike, this amounts to a more strategic and subtle understanding of AI and digital natures than one that glibly pits a supposedly 'social' digital capital against an unproblematized 'nature' that could or should be analyzed separately from it.

AI time is not the time of living labor

The point can also be expressed in terms of time, uncertainty and human and machine bodies. Unlike living labor, current AI does not have expectations about the future (Dennett, 1984). It does not anticipate (Nadin, 2017). It is neither surprised by anything that happens nor prepared to confront what humans would find surprising in the same way that living beings are. Rather, it is a network of machines for 'curve-fitting' (Pearl, 2018) or accelerating and increasing production of human-made statistical predictions based on bodies of data manufactured, using living labor, out of past human experience (Agrawal, Gans et al., 2018; Pasquinelli & Joler, 2021). Its response to specific failures of prediction is simply to work toward better predictions, by incorporating information about those failures into its models or by repeatedly challenging those models with masses of synthetic information formulated to probe their limits. Its procedures for improving predictions are not aimed at the goal of minimizing the possibility of unpleasant surprises, because the machines do not have the holistic framework prerequisite for concepts of unpleasantness or surprise, or correlated concepts such as trust. AI has few measures for helping capital effectively cope, in the way that living beings do as a matter of course, with, for example, the inevitability of future predictive failures deriving from radical uncertainty (Knight, 1921; Taleb, 2007), the dangers of which are often amplified by AI and other complex systems themselves (Perrow, 1986; Pfeiffer, 2016). Instead, it tends to model uncertainty on statistical probability, as if taking a bit too literally Joseph Butler's 1736 injunction that probability is the "very guide of life," implicitly basing itself on the premise that improving predictions without limit will eventually obviate the need for decision-making under radical uncertainty altogether. Stuck in a loop that keeps manufacturing more and more 'dead' labor, AI cannot by itself help capital circumvent its need to struggle with the ever-increasing number of cheap but experientially-skilled living workers required to tend the algorithms.

To put it another way, most current AI is designed in a way that accentuates the narrowness of modern institutions' and intellectuals' continuing, self-interested class commitment to a Cartesian – and in many ways 'white' (Mills, 2014) – fantasy model of human action that dichotomizes plan from implementation, training from deployment, program from execution, information from materiality, thought from action, discourse from matter, representation from reality, idea from object, image from thing, framework from content, intellect from physics, culture from nature or mind from body (Mitchell, 2002; Suchman, 2006; Hayles, 1999; Pfeiffer, 2016; Chesterton, 1922). As N. Katherine Hayles (1999: 2) remarks, it is "when information loses its body" that the performative equation of humans and computers implicit in the phrase ‘artificial intelligence’ becomes “especially easy, for the materiality in which the thinking mind is instantiated appears incidental to its essential nature.” Still largely constrained by an ideology according to which plans are “cognitive control structures that universally precede and determine actions” and are “not only necessary but also sufficient for an account of human activity” (Suchman, 2006: 13; but see Brooks, 2002), AI typically deals with failures of an algorithm to solve the ready-made problems with which it tends to be concerned by ‘going back to the drawing board’ incessantly – sometimes hundreds of times per second – for yet another prediction, plan or model. This is what it calls ‘learning’ (Toews, 2021). Some sense of the elitism inherent in this unworkable understanding of what planning in action consists of can be gauged from two simple examples. One is Lucy Suchman’s (2006) example of canoeists’ negotiations of river rapids. “The purpose of the plan in this case is not to get your canoe through the rapids, but rather to orient you in such a way that you can obtain the best possible position from which to use those embodied skills on which, in the final analysis, your success depends” (52). The canoeist needs both to project courses of action and to grasp that those projections rely on a “further horizon of activity that they do not exhaustively specify” where the work is “done within the rapids” (see also Dennett, 1984). A second example is the interpretation of contracts. Effective contracts depend not only on how precise, comprehensive and foresightful their language can be made at any particular point in time, or on the degree of automation that can be built into their enforcement, but also on a readiness to engage in the arbitration of contract law in the future, in acknowledgement of the fact that a contract will ultimately be whatever future legal and civil communities say it is following repeated rounds of negotiation and communal re-interpretation of its terms and implementation based on history and experience. By contrast, the AI-inflected theory of ‘smart’ contracts is continually boxing itself into an unfeasible project of finding a way of predicting every material event before it happens (Lohmann, 2020) – in a sense, an impossible battle plan that will survive every conceivable contact with ‘enemy’ reality (Keegan, 1976). Similarly, the self-driving vehicle that finds itself paralyzed for an hour at a stoplight stuck on red due to a passing parade, unable to seek workarounds in order to find an alternative way to its destination, can do little more than modify its algorithms for dealing with traffic signals (Brachman & Levesque, 2022). The new formulas may well be effective at dealing with future parades, but no amount of supplementary subroutines will by themselves add up to a holistic strategy for preparing for the inevitability of further unpredictable events, or for obtaining a good position from which to use a variety of those “embodied skills” (Suchman, 2006: 52) and understanding of the nature of interpretation that living labor acquires over long periods of reproduction and that make it able to adapt to as-yet unspecified situations on the fly.

This inadaptible, treadmill aspect of action-via-prediction is magnified in human-saturated environments in which the very making of a prediction via an algorithm becomes a datum that must be fed into the same algorithm. As Philip K. Dick (1956) and Ian Hacking (2006) have both illustrated in their different ways, humans respond to acts of being classified or having their behavior predicted or planned in ways that ultimately change themselves and consequently those classifications or predictions, which in turn elicit further responses, and so on. The same goes for human responses to AI-mediated acts of predicting how they will be classified. Even at the most quotidian scale, living workers allow for this ‘looping effect’ (Hacking, 1995) in ways that AI is designed not to do. Again, AI’s promise of liberating capital from reliance on bodily, inculcated human or biological skills of anticipation or expectation (Rosen, 2012; Nadin, 2015, 2017; Feignberg, 2014; Dennett, 1984) is likely to remain unfulfilled for the foreseeable future no matter how much it helps to improve or speed up statistical prediction.

One vivid way of expressing the contrast between AI time and living labor time is via the notion of accelerability. A striking feature of AI time is that, given the right mix of algorithms and processors (together with living labor busy manufacturing data behind the scenes), 19th-century thermodynamic energy is well suited to accelerate it indefinitely. The more abstract energy is available, the faster data can be processed to yield predictions. If ‘unsupervised machine learning’ free of human input could ever be developed, this acceleration would be constrained only by data volume and the physical and political limits to the worldwide spread of Carnot landscapes enabling on-off electromechanical switching in countless scattered data centers, supposedly removing speed limits on cognition. In short, the repetitive statistical operations of AI are one more reflection of capital’s characteristic compulsion “to repeat one and the same content” in linear fashion, up to an abstract, ‘bad’ or ‘false’ infinity, in order to escape the influence of “concrete, embodied, sentient, desiring, labouring beings” over the “pace and processes of production” (McNally, 2003: 6-9). Attempts to advance the mechanization of living labor’s recognition skills, for example, call for ever-speedier statistical correlation of data derived from millions of continuously repeated acts of ostension, labeling, tagging or matching of a formally identical and unvarying type. That is the troubled source of AI’s breathtaking ability to supply advertisers, intelligence agencies, police forces, education ministries or ‘nudge’ specialists (Thaler & Sunstein, 2021; Lanier, 2018) with real-time, repeated assessments of the future inclinations or performances of billions of individuals.

By contrast, the skills that make living labor indispensible for capital accumulation have a certain temporal ‘stickiness.’ Ecologically speaking, what limits the accelerability of interpretation, calculation, recognition, wayfinding and so forth in their proper senses is not the rising overall entropy of expanding Carnot landscapes (roughly, the long-term curve of diminishing returns to capital correlated with the increased dedication of global landscapes to wholesale energy conversions to feed AI machine networks and other industries). Nor is it the specific entropy of ‘information’ or data in the AI sense, which appears in the limiting case to revolve largely around the net computational energy degradation entailed by the need to erase machine memory periodically (Bennett, 2003) – and is currently inspiring the predictable cutting-edge research on how to slow computational entropy increases to save costs and expand markets (Wolpert, 2018; Wolpert et al., 2019). Among other things, it involves, rather (again, very roughly), the thermodynamics of life. Translating, meaning, believing, feeling, calculating, recognizing, wayfinding, and the other social practices that ground living capitalist labor are all embedded in the biological and social rhythms of that Moorean (2015) “web of life” in ways that make their acquisition and exercise difficult to accelerate beyond certain limits. For an animal or human child or worker, learning and exercising skills of classification, inference and all the rest entails rhythms involved in, for example, living physical organisms curiously approaching objects, looking behind or under them, and pushing and pulling them (Gibson, 1979; Shanahan et al., 2021) as well as years of engaging in open-ended material give and take with caregivers or mentors about how to face new challenges in which neither party is passive nor concerned only with a single result or set of objects (Vygotsky, 1930; Davidson, 2001). The rhythms involved can be slowed or quickened within fairly narrow bounds, in ways and with consequences that have been explored by child psychologists, Indigenous activists, social historians, Marxist theorists and others (Thompson, 1967; Glennie & Thrift, 2008; Schivelbusch, 2014 [1996]). But organizing and reorganizing Carnot landscapes is unlikely to be able to speed them up without limit after the manner of an idealized ‘deep learning.’ The temporal as well as spatial patterns of energy conversion and entropy flow that are directly and immediately relevant to the maintenance of such essential rhythms in living organisms and their societies are of a different order from the patterns demanded by the geographical imperatives of industrial/digital capital accumulation. Obstacles to the acceleration of production of proprietary predictions are also often recognized in Indigenous activism in statements such as “all data has a *whakapapa*” (Te Mana Raraunga, 2018: 2), implying the continuing necessity of slow genealogical linking of information about persons to ancestral contexts in land, sea and sky.

There are, in other words, biophysical as well as logical, social, economic and developmental reasons why the experience involved in cognition is "algorithmically incompressible," to quote a character in one of speculative fiction author Ted Chiang's (2010) stories, who discovers that it takes 20 years of growing up in a human society for even the most exceptionally-equipped and lifelike robot to become able to reason in a way that signals that it has become responsible for itself and others. Algorithms may be fast to execute, but concepts are slow, and slow concepts are needed to sustain fast algorithms. As Chiang (who is also a Microsoft employee) highlights, this temporal reality can be expected to have a dampening effect on capitalist interest in investing in machines that mimic humans or other animals too closely (see also Irani, 2015). Capitalists putting their fortunes into hiring 20 years of dedicated living human reproductive labor to get each individual ordinary robot worker up and running – in addition to covering the as yet unknown capital costs involved – would not have a bright business future. One of the few attempts, brilliantly carried out largely by women researchers, to develop 'sociable,' embodied AIs that could interact with humans (or one another) in some of the various ways that living labor requires (working together physically with strangers, making eye contact, gauging trustworthiness and so forth) never came close to creating employable living labor. It culminated, rather, in singular, fascinating and instructive spectacles in which, for example, one particular human caregiver showed that she had learned to 'read' and respond to certain simulations and cues that a machine offered in skilful ways, while the machine was demonstrated to be able to elicit and 'predict' certain repertoires of behavior of that particular caregiver, albeit without being able to respond appropriately to others (Suchman, 2006: 241-258; Breazeal, 2002; Menzel & d'Aluisio, 2000: 67-71). The human, in other words, still ended up performing all the living labor involved. The experience of such research programs suggest the relevance for AI of Judith Butler's (1993) Vygotskyesque argument that bodies (and the bodies of AIs aspiring to the status of living labor should be included) are built over long periods of time in a context of norms, not constructed in a single act nor as a means for merely 'embodying,' 'receiving' or 'carrying' ready-made 'information' (see also Pfeiffer, 2016, 2018).

These considerations regarding time, uncertainty and bodies should help reinforce the point that the dividing line between AI and living labor is physical, contingent, and institutional, not (*pace* religious and Cartesian critics of AI) metaphysical and absolute. There is, after all, no obvious reason why machines should not come someday to be able to explain, slowly, what they know about crosswalks in addition to being able to emit the string 'crosswalk' at the same moments when a human might do so. At some point, machines could conceivably come to have the sort of histories necessary to acquire the 'rudiments of the framework of thought' (Davidson, 2004), be treated as rational conversation partners, 'understand the world of the embodied collective and the different worlds of practice within sub-communities' (Collins, 2018), and create capitalist value alongside humans in the course of performing living labor. Indeed, it would change little in practical terms, as both Davidson and Dennett point out, if it were discovered that friends and colleagues have *always* been composed of computer chips rather than flesh and blood. It is even conceivable (if only just) that some day a society of such machines could be constructed at great expense whose collective learning processes were similar to those of human societies, yet whose varied, holistically-linked social histories in the physical world could *all* be speeded up indefinitely in tandem by energetic means in order to create an army of nonhuman living labor in short order. That is the way capital's dream of accelerating living work indefinitely might actually be realized. But this unlikely and surely unprofitable project is, understandably, not a part of current AI research programs. Nor is it likely that the pace of the biological, cultural and individual histories during which the basic skills of living labor are developed – whether those histories are histories of enzyme reactions, of evolved bodies and their sense organs, of abilities to anticipate (Rosen, 2012), or of powers to love and enjoy – is susceptible even in principle to being overridden by AI. The same goes for the slow social time that supervisors or fellow workers would need to take in order to assess the performance of an AI aspiring to the status of physically-embodied living labor as it responds to publicly-visible features of the world in linguistic and other bodily ways. With AI, in short, the venerable contradiction that, as Jason W. Moore notes, obtains between capital's reproduction time and the "reproduction time of the web of life" (Gaffney, Ravenscroft & Williams, 2019) has only sharpened.

None of this is to say that the mechanical enhancement of those 'middle' parts of actions of which Collins (1990) writes, such as calculations of the probabilities of particular events, will not continue to be highly useful to many sectors of capital, over the short to medium term, as 'dead' labor. On the contrary, AI is bound to continue helping capital make better and better predictions about the future choices of each of billions of individual consumers, the reflex responses that human drivers would make in dangerous situations, or the translations of particular symbol strings that would be suggested by thousands of professional interpreters. Twenty-first century prediction machines are sure to continue expanding their range of applications particularly in circulation, distribution, value realization and finance – as befits an age of financialization and massive infrastructure investment. But the incongruence of machine time with evolutionary, biological and social times reflects a range of obstacles to AI's actually replicating living labor and its depth of integrated social skills. No matter how much machine learning tries to speed up the realization of value in one place (Pfeiffer, 2022), the living labor to which it is tied will slow it down again in another. The question is what happens to that living labor in the process. As Kate Crawford (2021) observes, the question has never been "whether robots will replace humans," but rather the modes through which the humans standing behind the new machines become "increasingly treated like robots and what this means for the role of labor." In an instructive example, Amazon has concentrated a million living workers in warehouses in the US alone (Bishop, 2022) in order to help connect high-speed algorithm execution with the lower-speed physical human world. Predictably, pressures are now growing on Amazon executives to mechanize more (relatively slow) warehouse activities, not only to fight unionization but also to reduce and regiment the interpretive work done by humans in 'fulfillment centers' and delivery vehicles. But more mechanization means still more living labor being debilitated and provoked to protest at various points in the system, creating still more bottlenecks, disappointments and – for idealists of infinite acceleration – incentives to repress labor.

Indeed, here, as elsewhere, what ultimately fetters capital accumulation is what makes it possible in the short term, and vice versa. In reality, AI's integral inability to replace living labor is, for capital, its strength. In practical terms, there is no more reason for 21st-century capital to try to integrate Alexa, chess engines, blockchain, translation machines, face recognition devices and self-driving cars into an all-purpose AGI living labor substitute than there was for 19th- and 20th-century capital to compile power looms, paper mills, auto assembly lines into a single, all-purpose worker replacement device. Automation's so-called "last mile" (Gray & Suri, 2019) is a distance that, in the deepest strategic terms, capital neither wants nor needs to traverse or even approach. The mass of additional living labor AI requires is not something to be reformed away, but rather controlled through, among other things, the unlimited application of abstract thermodynamic energy and the unlimited expansion of Carnot landscapes and their frontiers of degradation. In this sense, spiraling energy use is not something 'accidental' about AI, but rather integral to its success. In AI, as elsewhere in capitalist society, profitability and ultimately crippling ecological contradictions are one.

Attributing living labor status to AI is fetishism

One final, summary way of underlining (and also exploring) AI's parasitism on a living labor that it is likely to continue to prove incapable of replacing is to redeploy fertile notions of fetishism and alienation in the contemporary digital context.

Fetishism is classically defined as an 'irrational' practice of treating a fragment of a putative whole as if it possessed a supercharged *je ne sais quoi* that animates or powers the remainder. Thus early European traders professed to see their African counterparts as arbitrarily endowing beads, trinkets, or bits of wood or cloth with inherent powers to heal, kill or rule (Pietz, 1985, 1987; Graeber, 2005), thereby setting Europe up, in contrast, as the bearer of an enlightened, supposedly 'nonarbitrary' subjectivity. Similarly, Freud saw fetishists as perversely getting pleasure from body parts or other objects that he was tempted to relegate to the category of mere genital 'substitutes' (Freud, 1963). Marx, meanwhile, found capitalists, workers and consumers to be endowing machines with magical powers divorced from the labor of the human communities that had created them. Workers were induced to credit production to machines rather than their own work, economic theorists to ignore not only reproductive labor but also the troops of outworkers surrounding every factory (Gray & Suri, 2019), and journalists to subtract humans from photographs of the machinic marvels of colonial rule (Barragan, 2018; Toscano, 2016) as well as from portrayals of 'pristine nature' (Mann, 2006). However, as thinkers such as Marx (2004 [1867]), Octave Mannoni (1969), Slavoj Zizek (1998) and David Graeber (2005) have stressed, fetishism – what Graeber called a human tendency to treat the things humans create as "gods under construction" – is far from being some sort of ignorant 'mistake' or oversight that can be eliminated through 'unmasking.' It is, rather, a far more deep-seated, enduring, creative and productive phenomenon. As Marx and his followers have repeatedly noted, for example, fetishism goes all the way down into, and rises up from, every 'technical' feature of assets, commodities, capital, money and industrial machines (Pietz, 1993; Hornborg, 2001, 2011; Nelson, 2021). Moreover, people tend to be fetishists in practice even (or especially) where they are not so 'in theory' (Mannoni, 1969: 9-33; Zizek, 1998). Scientifically-trained United Nations consultants, for example, may not individually believe that there is such a thing as renewable energy, but their job descriptions often require them to act as if they did during their entire working lives.

Fetishism is no less technologically and economically significant in the 21st century than it was in the 19th. As Phil Jones (2021) astutely observes, today's "data fetish," in eliding the fact that this supposedly "ethereal, elusive substance is the result – like hardware – of human labor" trained by human childhood experience, is crucial in directing attention away from the "hidden abode of automation" where digital capitalist value is busily being created: a "growing army of workers cut loose from proper employment and spasmodically tasked with training machine learning" via platforms with names like Amazon Mechanical Turk, Zhubajie, Appen, Hive, Scale, Playment, Clickworker, Mighty AI, M2Work, Samasource and Deepen AI or earlier labor assemblages like ImageNet (Russakovsky, O., Deng, J. et al., 2014; see also Pasquinelli & Joler, 2021; Crawford & Paglen, 2021). Many of these workers are what Jones (2021) calls the "subemployed" or partially-employed, who have been expelled by the wage labor system's overcapacity into a state of permanent precarity, indebtedness, and fusion with the 'reserve army' of unemployed amid de-industrialization and continued urbanization. Many are refugees, prisoners, or other forms of cheap or zero-cost captive labor (Chen, 2019). Many are women also engaged in full-time reproductve work. Some have high-level training but are otherwise unemployable in a deteriorating economic system. Taken together, the platforms that bring them together to perform billions of disjointed micro-activities daily for shifting congeries of distant companies already figuratively house many more millions of workers than Walmart and the other more conventional super-employers of the service sector combined. The human-ecological effects of their work, as Jones notes, are debilitating in ways that are somewhat different from those of more conventional capitalist labor.

In addition, most workers creating value in the digital sector are not paid at all, merely exchanging their labor for platform privileges. One reason for Facebook's prominence in the global economy, for example, is that despite having only around 48,000 paid workers, it has been able to recruit an additional 2.6 billion unpaid workers to donate labour to the firm's numerous data centers, generally on a daily basis and with little overhead per worker, in the form of simple interpretive interactions that workers voluntarily digitize into raw material for predictive algorithms using the mobile sensors and processing devices that they themselves have purchased. To put it another way, only 0.00001 per cent of Facebook's workers constitute a direct wage cost for the company – less than the proverbial rounding error (Laney, 2012). Each of those paid workers, moreover, generates for the company over US$400,000 in profit on average – the highest figure among the five Silicon Valley tech giants (Pfeiffer, 2022: 205). Amazon's AWS (Amazon Web Services), the company's cash-cow cloud platform, is another mechanism the sources of whose immense profitability (Ali, 2022) – the centralization of private property rights in the 'dead' or digitized labor gleaned from the unpaid work of billions of humans around the world (TechTarget, n.d.) – are concealed in the data fetish. Also vanishing into the data fetish is the colonial nature of the AI labor system, whereby the highest rates of exploitation can be achieved in places like Kenyan refugee camps, shared rooms in Chinese apartment blocks, and around Indian or Philippine kitchen tables (Jones, 2021; Couldry, 2019; Hao, 2022; Yuan, 2019; Pasquinelli & Joler, 2021). Occasionally, AI is 'faked' even more blatantly, as when operations that are advertised as being performed by machines crunching data are in fact carried out wholly by humans (Huet, 2016; Gray & Suri, 2017). What with all this data fetishism, it can be no surprise that most journalistic attention on AI focuses less on the new world of labor exploitation and platform rent than on, say, state surveillance, censorship policies, or manipulation of the public during electoral campaigns.

In the literature on artificial intelligence, commentators have also frequently noticed fetish-like powers being attributed to algorithms (Thomas et al., 2018) and source code (Chun, 2008) as well as to the industrial machines of which IT constitutes a newly-emerged species (Hornborg, 1992, 2001, 2011). Indeed, the work of sociologist Harry Collins (2018) suggests that the daily labor of attributing human powers to machines – what might be called 'fetish work' – is, across the AI sector, economically fully on a par with the more familiar repair, care and coordinating work that machine users constantly have to put in to make AI productive for capital. Collins notes, for example, that it is part of the technical design of user interfaces to conceal the labor that humans put in to make machines functional (see also Suchman, 2006; Taylor, 2018). For several billion socialized children and adults, many instances of digitizing acts of recognition, wayfinding or inference are now so easy and fun that they seem unworthy of the name labor (Pfannebecker & Smith, 2020). No programming or explicit translation into machine code is involved; all that smartphone or computer users have to do is recognize, type or point, and press 'send'. This is the relatively benign side of the "immense leap in the devaluation of labor" described by Silvia Federici (2010) that has been accomplished by the computerization of production. Moreover, as computer scientist Lilly Irani (2015: 231) points out, fetishizing algorithms and machines is key to making start-ups attractive to investors and speculators as 'technology companies' rather than 'companies for exploiting masses of marginalized human laborers'. "Workers must remain out of sight" of the public and, to an extent, of each other, for IT finance to function (Jones, 2021).

The contribution of this article to the fetishism discussion is to offer a reminder about a deeper but neglected aspect of each of these fetishes. This is the attempt to stabilize everyday cognition itself (and hence living labor) in 'object' form by allowing or encouraging some of the 'middle parts' of action identified by Collins (1990) to stand in for the whole of interpretation and other types of human labor – or to 'condense' into a mysterious process of quasi-digestion internal to individual biological bodies or machines what is in fact the co-evolution of changing and unpredictable physical environments with interpretation abilities exercised and developed by bodies in society moving through time along physical pathways. Today's fetishism about data, algorithms, machines and so forth has a long heritage in Western traditions of viewing knowledge as a matter of ‘privileged representations’ (Rorty, 1979, 2001) rather than answerability to conversational partners, human or otherwise. This tradition has always obscured the political nature of cognition. Indeed, the forebears of ‘data’ in the tradition of philosophical empiricism supposedly derived authority precisely from being a completely inhuman Other waiting to be ‘represented’ in self-contained schemata whose appropriateness could be assessed only by specialists (Davidson, 1973, 2001; Rouse, 2002; Rorty, 1979, 2001; Levine 2020). But this fetishism has been turbocharged in contemporary AI research, as witness one prominent computer scientist’s search for a ‘master’ algorithm capable of mutating itself in such a way that ‘all knowledge – past, present, and future – can be derived from data by a single, universal learning algorithm’ (Domingos, 2015: 26). Other experts believe that someday machine learning will be ‘unsupervised’ (Collins, 2018; Bechmann & Bowker, 2019) or even that today’s “data deluge” will ultimately make modelling and hypothesizing by human scientists obsolete (Anderson, 2000). While respecting the power of such fetishes, critics of AI need also to acknowledge the ‘misrecognitions’ that are involved, just as critics of capitalism more generally constantly need to find new ways of challenging commodity and money fetishism. In the 21st as in the 19th century, coming to terms with capitalist mechanization means carefully working through the material fetishisms that partly constitute it, which, when examined, help reveal its ecological contradictions and vulnerabilities.

Three aspects of fetishism that remain particularly neglected in today’s academic literature on AI and digital society are the following:

(a) What the logician W. v. O. Quine (1961 [1953]: 47-48) once called the ‘idea idea:’ the notion that meaning is a mental or physical entity or thing.

An exceptionally clear expression of this fetish can be found in a recent primer on machine learning published by MIT Press (Alpaydin, 2016: 109):

> “Consider machine translation. Starting with an English sentence, in multiple levels of processing and abstraction that are learned automatically from a very large English corpus to code the lexical, syntactic, and semantic rules of the English language, we would get to the most abstract representation. Now consider the same sentence in French. The levels of processing learned this time from a French corpus would be different, but if the two sentences mean the same, at the most abstract, language-independent level, they should have very similar representations. Language understanding is a process of encoding where from a given sentence we extract this high-level abstract representation, and language generation is a process of decoding where we synthesize a natural language sentence from such a high-level representation. In translation, we encode in the source language and decode in the target language. In a dialogue system, we first encode the question to an abstract level and process it to form a response in the abstract level, which we then decode as the response sentence.”

In the fetishes that help constitute connectionism (one machine learning approach), meanwhile, the place of this ‘high-level abstract representation’ happens to be taken by a more physical magical object, the ‘neuron’:

> “The idea is that neurons correspond to concepts and that the activation of a neuron corresponds to our current belief in the truth of that concept. Connections correspond to constraints or dependencies between concepts. A connection has a positive weight and is excitatory if the two concepts occur simultaneously—for example, between the neurons for circle and ‘6’—and has a negative weight and is inhibitory if the two concepts are mutually exclusive—for example, between the neurons for circle and ‘7’ … The basic idea in connectionist models is that intelligence is an *emergent property* and high-level tasks, such as recognition or association between patterns, arise automatically as a result of this activity propagation by the rather elemental operations of interconnected simple processing units” (95-96).

Here the material social and political practices of interpretation or translation, instead of grounding meaning and belief (and thus living labor), vanish into fetish objects into which meaning-making has been figuratively condensed and depoliticized. For very tangible political reasons, interpretation or translation becomes conceptualized as the discovery of fixed, shared magical objects rather than the open-ended, essentially political practice of social interaction that in reality is what gives rise to meaning (Lohmann, 2021e). Although Quine's phrase 'idea idea' is a handy shorthand for this fetish, and his arguments for the indeterminacy of translation (Quine, 1960) fundamental to its critique, the fetish is perhaps more effectively dissected in the work of Quine's student Donald Davidson (1984, 2001, 2004) and of anticolonialist historians, linguists and literary and legal scholars including Lydia He Liu (2000, 2006, 2013, 2019), Naoki Sakai (1997, 2006), Richard White (2010 [1990]), and Boaventura de Sousa Santos (2005) as well as by Vygotsky (1930) and representatives of numerous Indigenous traditions (de la Cadena, 2010; Viveiros de Castro, 2004; Rivera Cusicanqui, 2012).

The arguments of this diverse group of thinkers would obviously need a long shelf of books to synthesize, but some indicative fragments of the critique of AI's fetishism about interpretive living labor that is implicit in their work should at least be set out briefly as follows, if only because of their unfamiliarity to many geographers and other scholars. The work of interpreting or translating does not consist of recognizing pre-existing, communication-ready meanings in the minds of speakers of one idiom and then transferring them to the minds of speakers of another, but rather of 'producing difference' (Viveiros de Castro, 2004), stimulating the flouting of expectations, and helping to create or invent provisional meanings and beliefs on the spot collectively in the course of power-laden social interactions (Liu, 2000, 2006, 2013, 2019). Language understanding is not a process of extracting a (fetishized) "abstract representation" (Alpaydin, 2016) from – to take one example – the use of the Chinese character '夷,' nor translation a process of 'decoding' or transferring that representation into – to use the same example – contexts in which the English string 'barbarian' is used instead. Instead, the "hypothetical equivalence" (Liu, 2000: 13) expressible as '夷' = 'barbarian' was created during the 'intra-action' (Barad, 2006) between the British and Chinese empires in the 19th century in a "dynamic process of meaning-making" that went on "*between* or *among* languages as well as within a single language" (Liu, loc. cit.; see also White, 2010 [1990]). It is an intra-cultural "supersign" (Liu, 2006: 31-69; 2013) that derived from a particular political struggle in which the British used it as a justification for condemning and censoring Chinese texts. By the same token, productive communicative labor in the workplace is not directed at halting the interpretive process at an objectively 'correct' message to which one worker or boss has privileged or unmediated access and which is then transmitted with minimum interference or 'noise' (Shannon & Weaver, 1963) to another. Rather, it proceeds by "never assuming communality or taking comprehension for granted" (Morris, 1997; see also Robinson, 2017; Zizek, 2017). Nor is there anything 'internal' to ethnic/national 'languages' that bestows final authority on what count as the correct meanings for their words. As Sakai (2006) notes, from an anti-imperialist perspective languages are best conceptualized as non-countable, or as Davidson (1989: 446) puts it, there is in fact "no such thing as 'a' language" in the sense posited by many philosophers and linguists, many of whom are part of the AI tradition. Rather than being a matter of repeatedly trying to locate, compare, swap and mediate among fetish objects, interpretation is, to borrow terms derived from certain Indigenous Amazonian intellectual conceptions of translation, a process of "controlled equivocation … controlled in the sense that walking may be said to be a controlled way of falling" (Viveiros de Castro, 2004).

(b) The fetish that treats interpreting, learning, calculating, wayfinding, recognizing and so forth as outcomes of internal, hidden, quasi-digestive processes.

This fetish extrapolates from the uncontroversial fact that the brain (or analogous arrangements in silicon) are essential to interpretation, recognition, wayfinding and so forth to speculation that these processes should be explicable without reference to social practice. In the words of Lucy Suchman (2006: 257), it constitutes a “model of humanness as a set of separate components that need to be incorporated into a coherent whole” in an individual who only then is “acculturated into a set of social relations.” One such fetish is crisply reproduced by Alpaydin (2016: 85-86) in a description of artificial neural network engineering:

> “Our brains make us intelligent; we see or hear, learn and remember, plan and act thanks to our brains. In trying to build machines to have such abilities, then, our immediate source of inspiration is the human brain, just as birds were the source of inspiration in our early attempts to fly. What we would like to do is to look at how the brain works and try to come up with an understanding of how it does what it does [but] to have an explanation that is independent of the particular implementation details.”

The great pioneer of 20th-century therapeutic efforts to gain some perspective on this fetish is perhaps Ludwig Wittgenstein, but anti-mechanists in biology such as Robert Rosen (2012, 2013) have usefully come at the issue from complementary directions. Again, exploring how and why brain, neural network or silicon fetishes cannot elucidate Sellars’ “logical space of reasons” where living labor abides would require more space than is available here, but the literature is very easily accessed (e.g., Wittgenstein, 1953, 1978, 1980; Shanker, 1998; Davidson, 2004; Collins, 1990: 12-16).

(c) The related ‘fauxtomation’ fetish that identifies recognition with ‘knowledge by acquaintance.’

This fetish mediates, for example, the current wave of informal, micro-work ‘subemployment’ in the global South (Jones, 2021), in which, for example, Tesla exploits thousands of crisis-devastated Venezuelans at below-minimum wage to identify or annotate the street-view camera data that its driverless vehicles use to navigate traffic (Chen, 2019; Hao & Fernandez, 2022). In fact, two twinned fetishes are involved, one about humans, the other about AI. The first holds that it is sufficient for human trainers of AI to be able to recognize crosswalks as crosswalks that they have been shown crosswalks in the past. In the fetishist’s mind, the matching of crosswalks in an individual’s visual field with the string ‘crosswalk’ (as well as perhaps some further matchings) obviates any longer, more complex socialization process involving the acquisition of a larger network of beliefs, meanings and feelings about many things in the world that is required in reality for the ability to identify crosswalks correctly (see the section on holism above). The image is one of small children’s ‘acquiring’ a concept ‘in completed form” (Reigeluth & Castelle, 2021: 92) in one fell swoop through passively incorporating a label provided by authority and then moving on to the next task, and so on, rather than of their interacting with their human and nonhuman surroundings over the long term while tackling a whole range of challenges simultaneously. Twinned with this fetishistic image of humans is a parallel image of AI itself. It is assumed that for AIs, too, authoritative, dyadic acts of ‘matching’ exposures to crosswalks with various symbol strings (and perhaps further dyadic acts of matching exposure to those strings with exposure to other strings and objects, etc.) will, given the right algorithms, eventually result in the ability to recognize crosswalks. Again, the actual ‘ecology’ of learning to identify crosswalks is occluded in the fetishization process. There is little discussion about the fact that even ‘autonomous’ vehicles that differentially respond to crosswalks better than human drivers are unlikely to be able to answer most ordinary questions about crosswalks and justify those answers. Any problems that capital encounters by buying into this conception of the recognition of crosswalks and other objects, it is often assumed, can be solved simply by repeating the fetishistic ritual countless times, with the aid of big data and fast processors (Li, 2015). The ecological point is that fetishizing endless repetitions of acts of ostension is part and parcel of AI’s enormous expenditures of both living labor and thermodynamic energy (see below). In the 21st century, cognition fetishism is as closely entangled with the global degradation of human and non-human nature as garden-variety commodity fetishism is.

One example of a therapy for working through this fetishization process is the Vygotskyan (1930) treatment of child development alluded to in the last paragraph, according to which a word used by a living worker “enfolds a generalization which cannot be understood as a preestablished relationship between a signifier and its meaning” and relates not “to a single object, but to an entire group or class of objects” (Reigeluth & Castelle, 2021: 92). Another example is Wilfrid Sellars’ aptly-named “myth of Jones” (1997 [1956]), which is not so much a logical refutation as a speculative historical narrative demonstrating how it might be possible to avoid the common AI presupposition that recognition and classification are founded on acts of labelling or tagging that could in principle float free of the give and take of human linguistic communities. Again, since there is no space here to explore the diverse, mutually-reinforcing literatures around such therapies and critiques, it will have to be sufficient to point out that it openly available and has been discussed in various academic and technical circles for the better part of a century, yet is generally ignored in scholarly debates on ‘digital natures’ (see Table 1). For geographers, Marxist theorists and others unfamiliar with this literature, it may be useful to offer some orientation in Table 1, which is not intended to be anywhere near exhaustive. The rows in the table correspond, roughly speaking, to various (overlapping) traditions that can help undermine the idea or fetish according to which AI is or soon will be providing living labor to capital. The columns provide some names, summary points, and catchphrases associated with each tradition.

Table 1
Why AI is not ‘artificial labor power’ and does not create value for capital: some neglected resources

Tradition (presiding spirits)	***Other figures***	***Summary points***	***Catchphrases***
Marx (1859)	Caffentzis (2013), Ekbia & Nardi (2017), Jones (2021), Gray & Suri (2019), Taylor, 2018), Antunes (2013), Pfeiffer (2016, 2018), Carbonell (2022), Crawford (2021), Couldry & Meijas (2019), Terranova (2004), Scholz (2013), Zuboff (2019).	Capital needs living labor to animate dead labor (machines) even as it degrades the former in the process. Machines do not create new capitalist value.	“Marx’s theory of machines needs to be extended to include the Turing machine” (Caffentzis, 2013: 178).
Wittgenstein (1953)	Davidson (2001, 2004); Collins (1990, 2018); Collins & Kusch (1994); Shanker (1998); Haugeland (1998), Rouse (2002); Sellars (1997).	Rules do not interpret themselves. A machine could not have only one belief or desire. A great deal of social ‘stage-setting’ is needed before acts of labeling can play a role in knowledge acquisition.	Turing machines “are humans who calculate” (Wittgenstein, 1980: §1096). “Images do not describe themselves” (Crawford & Paglen, 2021).

Vygotsky (1930)	Reigeluth & Castelle (2021).	Interpretive work cannot be understood as an event of connecting a signifier and its meaning.	"A mature concept involves the whole totality of its relations, its place in the world" (Vygotsky, 1997 [1930]: 100).
Quine (1960); Sakai (1998, 2006); Liu (2000, 2006, 2013, 2019); White (2010 [1990])	Robinson (2017); Morris (1997); Davidson (1984, 1989, 2004b), Rorty (1979).	Translation is prior to meaning, not the other way around. Translation on politically-charged "middle grounds" (White, 2010 [1990]) creates meaning rather than simply communicating it.	Seeing translation "as a process of establishing equivalence" is a "misapprehension" that "derives from the confusion of the act of translation with its representation" (Sakai, 2006: 71).
Andean/Amazonian thinkers, Heidegger (1977), J. J. Gibson (1979).	De la Cadena (2010), Kohn (2013), Viveiros de Castro (2004), Rivera Cusicanqui (2012), Lenkersdorf (2008), Ingold (2000), Rouse (2002), Dreyfus (1992), Yuk Hui (2014).	Knowledge or intelligence is not a matter of representing a world separate from humans, nor does communication consist of swapping reified representations.	The "way human beings interact with the world is not necessarily mediated by representations" (Hui, 2014).
Bernstein (Feigenberg, 2014), Suchman (2006), Rosen (2012), Dennett (1984).	Nadin (2015, 2017); Mitchell (2002); Agre (1997).	Anticipation and expectation, as key aspects of cognition in unfamiliar situations, are problematic for an approach centered on accelerable execution of algorithms, probability calculations and dichotomies between planning and execution.	"We want a … robot to be 'surprised' by [the unexpected]" (Dennett, 1984). Projections rely on a "further horizon of activity that they do not exhaustively specify" (Suchman, 2006).
John McCarthy (1958).	Winograd (1975), Minsky (1975), Shanahan (1997), Lenat (2019), Brachman & Levesque (2022), other leading computer scientists.	The 'frame problem' in AI research, the 'problem of common sense, the 'problem of background knowledge,' etc.	"Common sense is the dark matter of artificial intelligence" (Oren Etzioni) (Knight, 2018).

It can hardly be re-emphasized heavily enough that the topic of this Table, as of the rest of this article, is ultimately 'digital natures'. What is elucidated by the intellectual figures that the Table lists are, above all, the *ecological* contradictions of AI, which are more or less the same as those of 19th-century industrial machine networks. In any specific business case, AI is applied to further the automation of production, circulation, consumption or finance by mechanizing one or another of the basic interpretive skills that most people acquire during childhood – recognition, translation, perception, calculation, memory, inference and the like – via the rapid production of trillions of predictions. Paradoxically, however, to succeed in any concrete automation project along these lines, AI must, as the work of the thinkers in Table 1 implies, both gain access to, and become an instrument for mobilizing, vast new pools of *un*automated living human labor power on an extremely wide scale. Moreover, any victory that capital achieves by mechanizing away some needs for interpretive labor on one site has to be paid for both by an increased overall need to regiment, harvest or repress living work elsewhere (Caffentzis, 2013) and by the expenditure of thermodynamic energy needed to drive the massively repetitive electromechanical processes that are required for even the most inadequate simulacra of certain aspects of interpretative labor. As elsewhere, the private ownership of dead, 'objectified' labor is organically connected to the exploitation, control, surveillance and degradation of the living. The snowballing 'failures' of AI to create value for capital mandate snowballing ecological devastation and harm to human workers if accumulation is to continue. That is the burden, for this article, of the various schools of analysis sampled in Table 1. The table merely attempts to bring up to date the hard-won Marxian wisdom that, if profit is to be sustained, expanded capitalization entails an even greater expansion in the colonial appropriation and exploitation of unpaid work in living beings and living landscapes (Moore, 2015). It aims at helping to discern the evolving outlines of AI inside both human and nonhuman nature.

What remains is merely to sketch in a bit more detail the energetic structure of AI in particular. The following section, in documenting the link between AI and the ecological transformations involved in its need for commensurated thermodynamic energy, underlines fundamental continuities with the colonial energy geography of the 19th-century industrialization that still defines global capital.

5. AI's energy geography expands and entrenches the energy geography of 19th-century industrialization

As this article has argued, AI's hunger for new, ultra-cheap sources of living labor is matched by its drive for ultra-cheap colonial expansions and rearrangements of Carnot landscapes. Contemporary machine learning methods that "leverage computation" (to borrow the phrase of DeepMind's Rich Sutton [2019]) are designed to take advantage of, and in turn help sustain the need for, the commensurated energy that industrial capitalist society has made cheap. Today's data centers are by themselves among the world's largest consumers of electricity (Cook et al., 2017), and it is estimated that they will use three to 13 percent of all electricity by the year 2030, compared to one percent in 2010 (Couldry, 2019: 234; Andrae & Edler, 2015; see also Masanet et al., 2020; Jones, 2018). Taken together, digital technologies, including network exchanges and fiber-optic connections, currently mobilize 10 per cent of the world's electricity (Ferrebouf et al., 2019). The IT machine networks that facilitate and require the vacuuming up of all those new layers of human work will probably soon constitute the "most extensive thing built by the human species" (Pitron, 2021). The carbon footprint of the world's computational infrastructure is increasing even faster than that of the aviation industry, with the tech sector projected to contribute 14 percent of global greenhouse emissions by 2040 (Belkhir & Elmeligi, 2018). China's data center industry – still mostly powered by coal – is expected to increase its electricity consumption by two-thirds in the five-year period ending in 2023 (Greenpeace, 2019).

Over the last few years, accelerated flattening of entropy slopes owing to the growing mechanization of interpretation has been documented worldwide, along with the attempted rebuilding of those slopes through the export of entropy to sacrifice zones situated well apart from local machine environments. One factor in this process is what Nicole Starosielski (2021: 216) calls the “coldward course of computing” driven by the need for cheap refrigeration to remove the enormous quantities of heat expelled during the energy conversions involved in AI’s massively repetitive electromechanical processes. Ambient temperature is now a critical zero-cost resource that companies running data centers need to leverage, alongside tax benefits, electricity costs, the desperation of hollowed-out local governments for investment, and other site-specific features including the possibility of channeling waste heat from data farms (like waste heat from other industrial processes) to municipal use (Velkova, 2021, 2016). In many cases, heat vented from computer circuits winds up being absorbed by water taken from local communities and habitats (Ensmenger, 2013), raising the temperature of lakes, rivers and oceans as well as the air.

If those chilly data-center locations are also sparsely-populated regions with high sunk investments in surplus hydropower – such as Georgia, Sweden, Norway, Iceland or the US Northwest – or, for that matter, extra coal-fired generating capacity, and are organized in a way that saves some costs of managing political resistance, then so much the better for AI companies (BitMEX Research, 2017; Starn, 2020; Butler, 2019; Lally, Kay & Thatcher, 2019; McKenzie, 2021; Pedersen, 2019). Here too the key is cheap access to steep entropy gradients the costs of whose eventual erosion can be passed on elsewhere. For example, whatever their original purpose, hydroelectric dams eventually become incapacitated by silt and have to be abandoned, since the energy costs of digging out their reservoirs is either prohibitive or dependent on ‘exporting’ even more entropy to other sacrifice zones whose exploitation could be even more cheaply accomplished. Similarly, landscapes poisoned by mines or industrial emissions remain long after the myriad floating-point operations that their raw materials make possible in the service of the speedy circulation of commodities. Such terrains are often difficult to recuperate for their inhabitants.

As this article has argued, it is unlikely that the “compute maximalism” (Crawford, 2021: 43) that helps drive this geographic process could ever weaken under the capitalist logic of the mechanization of interpretation; quite the contrary. As Starosielski (2021: 218-219) observes, the “process of grappling with climate change and energy costs has not involved diminishing or reducing the amount of data or transmission” but rather focuses on the alteration of “computation’s thermal contexts.” “Burning computation cycles” (Hu, 2015) is simply the best way of achieving incremental efficiencies in the mechanization of interpretive labor as long as the wastes, heat and deterioration connected with its energy system can be concealed and shifted at low or zero cost. Aided by the growth of digital labor platforms and the Internet of Things, the creation, capture, duplication and consumption of data is set to increase from 79 to 181 zettabytes between 2021 and 2025 (Statista, 2022). The period 2016-2018 already saw the manufacture of 90 per cent of the data then available in the world (Marr, 2018). As of 2019, digital energy consumption was growing by about nine to ten per cent annually worldwide (Hughes et al., 2019). OpenAI (2018) has estimated that since 2012, the amount of compute used to train a single AI model has increased by a factor of ten every year. In 2019, the CO_2 emissions resulting merely from the training (not the use) of a single deep-learning natural language processing model was running to 284 tonnes, five times that of a car driven for a lifetime or 125 round-trip flights from New York to Beijing (Strubell, Ganesh & McCallum, 2019).

Other factors are bound to exacerbate the trend. The need for data redundancy means that as a rule, cat videos are stored in at least seven data centres across the world and gmails in six, while all IT infrastructure needs to be be systematically oversized in order to anticipate traffic spikes and prevent service interruptions in the case of systemic breakdowns. For the same reason, according to computer scientist Anne-Cecile Orgerie, routers are expected to run at only 60 percent of their capacity (Pitron, 2021). Machine-to-machine activity driven by the mechanization of interpretation also plays its part. In the financial sector, machine-to-machine traffic accounts for 70 per cent of global transactions and up to 40 per cent of the value of the securities traded (Pitron, 2021). Interpretation machines also integrate themselves more and more with other machines through connected homes, smart cars, drones, remote cameras and so forth. In addition to simulating human acts of interpretation, they are also recruited to unmask or counter other machines' simulations (Goswami, 2022). Many AIs, for example, are deployed to engage in mindless 'conversation' with the automated scammers that now infest the internet in order to waste their valuable time (Pitron, 2021).

The popular idea, often promoted by neoclassical economists, that improved 'efficiency' is capable of curtailing or reversing the energetic trends associated with this compute maximalism reveals a serious misunderstanding of the concept (Polimeni & Mayumi, 2015). Increased efficiency in the use of energy per unit of production of a particular commodity is perfectly consistent with increased wastefulness in the associated overall system of capital accumulation. Indeed, the two are often directly related to one another. The lesson applies to AI capital as much as to any previous form of industrial capital. Today, each unit computation is performed approximately one trillion times more efficiently than it was 70 years ago (Trustnodes, 2018; Routley, 2017; Dyson, 2012), a trend that continues. That record is unmatched even by the improvements in efficiency per stereotyped mechanical repetition associated with the first and second industrial revolutions. Yet, as with 19th-century industrialization, per-unit efficiency improvements (some of them accomplished via AI itself) necessarily only exacerbate the burgeoning violence, waste and 'inefficiency' of an overall system organized around capital accumulation (Foster, 2019) – including the system of reorganizing Carnot landscapes that constitutes the development of thermodynamic energy. With AI, capital has merely doubled down on the unsustainable dynamics of 19th-century energy geography, as is demonstrated by the conjoined trends of skyrocketing AI energy use, rapidly accumulating waste and improved efficiency per computation. It is not just that AI is built on, and operates in tandem with, older industrial technologies (Schaffer, 1994; Daston, 2018; Ensmenger, 2018a; Caffentzis, 2013: 127-200; Ghosh, 2020). Nor is it only that AI duplicates and in many cases increases rates of entropy increase associated with more traditional manufacturing. (While the ratio of the resources used and transported in the manufacture, use and recycling of a television set to each 'unit of service' [Ritthof, Rohn & Liedtke, 2002] has been calculated to be at most 1000:1, the corresponding ratio for a computer chip runs to 16,000:1 [Pitron, 2021].) It is also, more generally, that its own drive for efficiency, conjoined with the accumulation imperative, only extends and deepens the connections between growing labor exploitation and the post-1945 "great acceleration" (McNeill, 2014) of the despoilation of nature.

With 'reduced throughput' approaches impossible under capitalist logic, and 'increased efficiency' approaches ineffective in countering AI's growing aggregate energy and carbon dioxide footprint and its disruptive effects on IT business itself, AI capital is forced instead to resort to attempts at temporary colonial management of the thermal consequences. Following the lead of 'non-digital' capital (World Economic Forum, 2021; Shankleman & Rathi, 2021), corporations such as Google, Microsoft, Amazon, Baidu and many others have fallen back on promises to displace the heat and waste burden of the AI/abstract energy nexus onto territories where the adverse political ecological consequences can be expected, for a time, to be contained more economically. Today, no business sector is more strident than AI in advocating 'renewables,' 'offsets' and 'nature-based solutions' as a way of attaining 'net zero' emissions in the face of rising throughputs, more energy conversions, and accelerated increases in entropy (Apple, 2021; Harrabin, 2020; Smith, 2020). To take only one of thousands of examples, in place of reducing its transfer of carbon to the air, Apple, using a subcontractor, is annexing rights to the photosynthetic work that mangrove forests do to return atmospheric carbon to the biosphere (Lang, 2021). In this case, the subcontractor, Conservation International, also happens to be a top recipient of US$791 million donated in February 2020 by

Jeff Bezos of Amazon to promote similar activities to 'compensate' for – without halting – continued increases in energy conversions and resource use by industry as a whole (Lang, 2020). Like other industrial sectors, AI has also benefited indirectly since the 1990s from enormous state grants of private property rights in global carbon-cycling capacity to large power plants through emissions trading schemes, including that of the European Union. Under national and international law, these grants, together with carbon offsets, make it possible for AI's 'thermal responsibility' for opening new entropy doors to be diluted across the entire present and future surface of the globe and all its inhabitants, no matter how far removed they may be from the center of AI development or how little say they have in its direction (Lohmann, 2006, 2012).

The difficulties for such openly colonialist, temporizing attempts at 'cost-shifting' (Kapp, 1950) are essentially twofold. First, as explained in Section 2 above, reconstructing entropy slopes in AI cores by flattening them faster in colonized territories cannot but add one more increment of entropy increase to the overall earth system, increasing AI's global thermal effects simply as a function of the Second Law of Thermodynamics (Kleidon, 2016; Stapczynski, Rathi & Marawanyika, 2021). The new 'green economy' of renewable energy, offsets, 'carbon neutrality,' 'net zero' and 'nature-based solutions' can do nothing more than update and augment the colonial process by which AI continually 'exports' high entropy to, while 'importing' low entropy from, surrounding 'sacrifice zones.' Just as AI powered by coal, oil and gas leaves behind a trail of unusable local heat, carbon dioxide, poisons and waste, as well as warming at the global scale, so too AI powered by solar panels, wind turbines, hydroelectric dams, biomass and geothermal differentials leaves behind a trail of equally unusable local heat, similar poisons, similar waste and even, often, similar increments of carbon dioxide and global warming. Energy from biomass is one example. Even if biomass were used to replace rather than to supplement fossil fuels, its entropy cost in terms of devastated forests, soil degradation, transatlantic transport, and net combustion emissions would remain comparable to that of coal, oil and gas (Booth, 2018; Ravilious, 2020). Wind turbine electricity, meanwhile, necessitates forms of degradation intrinsic not only to increased mining of copper, cobalt, nickel and other metals from colonial zones, but also to increased exploitation of, for example, the balsa wood used to reinforce wind turbine blades (Bravo, Mendoza et al., 2021). That in turn leads to forest and soil degradation, damage to forest communities, and, again, increased climatic instability.

Carbon offsets are equally counterproductive from a thermodynamic perspective. All offsets are by definition designed to authorize continued emissions from underground fossil sources of carbon. That is, they aim at sustaining construction and reconstruction of Carnot geographies marked by increased energy conversion accompanied by generation of increased quantities of waste heat. Their justification is not that they cut the waste heat and other local wastes produced by industrial capital's energy conversions, but that they supposedly prevent increments of global atmospheric heating through professional management of carbon dioxide molecule movements. Two kinds of 'compensatory' measure are enlisted. Plantation, reforestation and other 'carbon removal' offsets (around four per cent of the total voluntary offset market) claim to be able to 'absorb' fossil-origin carbon in the atmosphere and safeguard it in new plant matter or underground caverns. Other offsets (approximately 96 per cent of the total) claim to be able to neutralize present fossil emissions by promising to reduce or compensate for hypothetical future emissions (Shankleman & Rathi, 2021). That is allegedly accomplished through projects involving renewable energy, efficiency, waste and land management, or 'avoided deforestation,' whose documentation claims that they either prevent emissions that would otherwise occur or compensate for them.

However, all of these categories of offset are nonfunctional or worse. 'Carbon removal' offsets, in addition to licensing continued fossil fuel conversions, place a burden on above-ground biotic carbon pools or underground reservoirs that they are unable to take on in biophysical terms (Mackey, 2013; Cuéllar-Franca & Azapagic, 2015). Plantations can even reduce the carbon-cycling capacity of the forests they replace (Osuri, Gopal et al., 2020; Shete, Rutten et al., 2016) and increase fire risk (Baffoni & Haggith, n.d.). Hence they are responsible for adding to net global (as well as local) heating. The remaining 96 per cent of offsets fail on other grounds. First, in order to put themselves in a position to claim that they are are compensating for industrial emissions, they have strong incentives not only to overestimate future emissions but also to implement industrial processes that physically increase them as much as possible, so that 'savings' can be made later. Second, offsets involve activities that directly or indirectly increase certain types of energy conversions as well as net entropy rates and net waste production. (While claiming to compensate for the fossil carbon emissions that they encourage, for instance, hydroelectric dams hasten or increase conversions of kinetic energy to heat while also creating conditions for increased emissions from, for example, land use changes and decay of reservoir vegetation [Deemer et al., 2016; Ocko & Hamburg, 2019]. The net effects of hydropower construction are worsened, moreover, wherever the addition of hydroelectric capacity merely supplements, rather than supplanting, the burning of fossil fuels. Plantations of the sort that are commonly aimed at absorbing or compensating for industrial carbon emissions, meanwhile, often result in soil degradation and water depletion, also pushing entropy rates higher [Carrere & Lohmann, 1996]. And so on.) In keeping with the geographic structure of post-18th century energy, 'green' energy projects necessitate a dynamic of continually expanding degradation of colonized lands and societies whenever they open entropy doors that would otherwise remain closed for the time being.

A second difficulty for AI's colonialist, temporizing attempts at 'cost-shifting' (Kapp, 1950) involving renewables, offsets, 'carbon neutrality,' 'net zero,' 'nature-based solutions' and so forth is the political resistance that they inevitably provoke. Any renewables development aimed at maintaining or expanding the global structure of 19th-century energy necessarily involves continued, indeed increased, extraction of cheap raw materials from the global South. Lithium, nickel, cobalt, rare earth and biomass and biofuel extraction is added to oil, coal and gas extraction, further devastating community life-spaces, angering many rural populations, and even making mining capitalists apprehensive (Koop, 2021; Lee, 2022; Riofrancos, 2021; EJOLT, 2022; Backhouse, Lehmann et al., 2021; Church & Crawford, 2018; Global Witness, 2022). Plantations, conservation schemes and wind and solar farms, frequently subsidized by offset income, entail contested land seizures and land-use restrictions (Cabello & Kill, 2022; Hamouchene, 2022; Dunlap, 2021; Lang, 2020). Indeed, speeding up the erosion of entropy slopes in colonized territories in order to preserve them in machine heartlands might be considered a generalized recipe for undermining the life-support systems of – and increasing unrest in – communities dependent on perennial streams, forest commons and the like. The dumping of toxic, high-entropy waste from the electronics industry in poor communities North and South (Abalansa, El Mahrad et al., 2021) has also sparked resistance. The potential of offsets in particular to incite continuing resistance is guaranteed by the fact that the very mathematics of offset calculation is colonialist. It is impossible to compute the carbon benefits of any particular increment of offset funding, and thus issue pollution permits, without inventing a class of colonized subjects who are so passive that their future actions become precisely predictable and counterposing them to a class of offset project executors who alone are endowed with the unpredictable agency to 'make a carbon difference' (Lohmann, 2022). All this makes it exceedingly unlikely that conflict over AI's exorbitant use of energy might someday be averted by, say, supply chains supplying lithium from Bolivia coming fully on line, or more wind farms being installed on the Tehuantepec isthmus. Even many AI corporate employees are becoming disgruntled with their bosses' 'net zero' rhetoric (Ghaffary, 2019).

In short, AI's attempts to mechanize new layers of living interpretive labor, far from interrupting industrial capital's cannibalization of the energetics of a living world, are only intensifying it, piling up problems for the future of AI itself. Much further research needs to be done on the distinctive geographic patterns of entropy door-opening characteristic of industrial capitalism's new digital phase, and the racial, patriarchal and class domination that make those patterns possible and cheap. Such research would trace and taxonomize the variety of cycles through which AI, using different arrangements of activation energies (Lambert, 1998), sets up, rearranges, flattens and reconstitutes millions of new gradients between low and high entropy worldwide. Understanding such processes will be essential in identifying the concrete, distinctive instances of political violence centred on AI's appropriations from human and nonhuman workers alike (Moore, 2015; Qiu, 2016) in the emerging 'digital natures' of the 21st century. Some of the colonialist parallels that will be useful to keep in mind are summarized briefly in Table 3.

Table 2
From Textiles to AI: 200 Years of Colonial Carnot Landscapes

Geographic process	***Post-18th-century mechanization of spinning, weaving, steelmaking, etc.***	***21st-century mechanization of interpretation, recognition, calculation, etc.***
Extraction of low-entropy materials	Expansion and exhaustion of fossil fuel, mineral frontiers	Expansion and exhaustion of fossil fuel, mineral frontiers
Waste exports (heat, CO_2, other pollutants)	Expansion and exhaustion of 'dumping frontiers' including contaminated or damaged human and other living bodies, landfills, the atmosphere, and (post-1960) offset territories	Expansion and exhaustion of 'dumping frontiers' including contaminated or damaged human and other living bodies, landfills, the atmosphere, and (post-2010) offset territories
Colonialist, racist, gender, and class differentiation	Management of borders separating zones of cheap extraction and disposal from zones where profit is accumulated	Management of borders separating zones of cheap extraction and disposal from zones where profit is accumulated
Enabling and constraining extraction from living labor	Extending wage labor relation; linked geographies of factory, sweatshop, home, commons undergoing enclosure	Pushing beyond the wage relation; finding new reservoirs of low- or zero-cost labor

6. Conclusion

By the first decades of the 19th century, early artificial intelligence devices were already appearing across the emerging industrial landscape of Northern Europe. Steam engine governors refined by James Watt and Matthew Boulton 'recognized' the speed of steam flow as part of a streamlined 'infomechanical relay between flows of energy and information' (Pasquinelli, 2015). Thermostats or ‘heat governors,’ co-invented by Andrew Ure, the ‘philosopher of manufactures’ and reactionary prophet of total labor control, provided industry with automatic feedback mechanisms by ‘sensing’ temperatures and ‘communicating the information’ to furnaces or boilers schooled in how to ‘read’ it, all faster and more reliably than a waged human could do (Beniger, 1989). Automated Jacquard looms enlisted as weapons against the restive textile artisans of Lyons ‘recognized’ symbol types and ‘translated’ them into one another (Essinger, 2004), eventually contributing to the early computer achievements of Charles Babbage and Ada Lovelace that Marx found so fascinating (Schaffer, 1994). Each of these AI devices was linked both to the contemporaneous “birth of energy” (Daggett, 2019) and to capitalist ambitions to extend control over living labor. Later on, interpretation machines were fused with humans in still other ways in autopilots and predictive antiaircraft fire control systems, further redirecting and restructuring living labor in the process. Many other novel human-*cum*-interpretation machine symbioses followed with the unfolding of the postwar computing age involving nuclear and thermonuclear weapon design and evaluation, command and control, cryptanalysis, radar, climate modelling, ‘numerical control’ in machine tool factories and genetic mapping and engineering (Dyson, 2012; Noble, 2011 [1986]). This article has described the continuation of this pattern linking labor struggles, capital, energy and industrial machines and their geographies into the digital ecologies of the 21st century (see Table 3).

Throughout this history, Marx’s famous line about industrial workers having to learn to “step to the side of the machine” (2004 [1867]: 497) has never signified less aggregate toil for humans; quite the contrary. For capital, centralizing control over the dead labor that needs no wages and can never revolt always has a contradictory cost: huge volumes of refractory living labor are needed to run the machines and forestall, among other things, the ever more consequential results of their breakdown. The descendants of the workers who prevented steam engines from dying or blowing up and took care of primitive thermostats and Jacquard looms must now breathe life into (and occasionally resuscitate) machine learning and the Cloud. And those workers, like their ancestors, must still somehow find their sustenance in the web of life. In a parallel with the first industrial age, ownership of the means of energy conversion and ownership of means of production of saleable predictions fuse in digital capitalism in a coordinated attack on living labor capacities.

Table 3
Some continuities and divergences between 19th-century ‘industrial natures’ and 21st-century AI’s ‘digital natures’

Variable	***19th-century industrial machine/energy networks***	***21st-century AI machine/energy networks***
What kind of skills are ‘mechanized,’ ‘heteromated’ or ‘fauxtomated’?	Weaving, spinning, copying, papermaking, steelmaking, farming, transporting, calculating, sensing (via thermostats or Jacquard looms), etc.	All of the above plus recognizing hitherto unseen characters, images, and faces; interpreting or translating previously unseen or unheard natural language strings (Google Translate, DeepL, Alexa, etc.); wayfinding in unfamiliar landscapes (self-driving vehicles); new levels of calculating, remembering, searching, learning, verifying, etc.

What kinds of de- and re-contextualization are involved?	E.g., isolating, standardizing, energizing, and re-coordinating physical motions broken off from human practices of spinning, weaving, farming, etc. – e.g., stretching and twisting fibers – so that the fragmented, stereotyped motions can be repeated at high speeds in the service of 'labor productivity'-cum-ecological degradation.	All of the above plus isolating fragments of acts of recognizing, remembering or wayfinding – e.g., responding to a crosswalk with 'crosswalk' – from their social, physical, developmental and historical contexts, and then using big data, statistical curve fitting, evolutionary algorithms and repeated on-off operations in powerful computers to repeat them in bulk at high speeds to produce predictions efficiently at ecological cost.
What kind of energy is required?	Abstract (19th-century thermodynamic) energy.	Abstract (19th-century thermodynamic) energy.
What kinds of (energized) repetition are involved?	Mechanical, stereotyped physical motions or 'gestures.'	Electronic or electromechanical off-on or floating-point operations.
What kinds of living labor are needed?	Monitoring, repairing, training, excusing, and caring for machines, detecting and discarding their 'errors', adapting social practices to accommodate them, choosing motions to be repeated, fitting machine actions to new contexts, fashioning kludges, supplying them with fuel and raw materials of appropriate quality, attributing labor power to them while concealing the human labor power required for their operation, etc.	All of the above plus labeling or tagging images or symbol strings; having and digitizing conversations; inferring causes; wayfinding and digitizing acts of wayfinding; choosing relevant data sets for machines to process, choosing modes of machine learning; clicking; correcting or superseding algorithms; correcting statistical curve-fitting; hiding the human labor required for machine operation, etc.
What are the contractual, temporal and spatial units of paid work involved?	The 'job' executed and paid over an hour, day, week or career, typically localized geographically.	The above plus subdivided cognitive reactions taking seconds or minutes – cheapened, miniaturized tasks redistributed among casualized, micro-contracted internet-connected workers organized in abstract 'global' space.
What are some categories of waged living labor involved?	Assembly line; outsourced piecework; plantation, mining, warehousing, clerical, transport, building and maintenance labor; ecological remediation; machine network construction; consumer construction; etc.	All of the above plus 'ghost work' centering on decomposed, Mechanical Turk-type tasks; fetish work; etc.

What are some categories of unwaged living labor involved?	Reproduction work; housework; commons maintenance; consumption work; love; ‘free gifts of nature,’ much of the work of ‘women, colonies and nature’ (Mies, 1986); unpaid work fixing the behaviour of machines; unpaid fetishizing of machines; etc.	All of the above plus playing, exchanging and constructing desire on Facebook, Twitter, Google, Amazon and Netflix; finding the way from place to place while monitored by smartphones; commanding and responding to Alexa; etc.
What kind of catchphrases are used to conceal the living labor involved?	“The machine is doing the work … is replacing labor … is a labor-saving device.”	“The machine is calculating … learning … evaluating”, “The future will be fully automated.”
How is the necessary living labor compelled, persuaded, surveilled, disciplined and regimented?	Wage contract, forced divisions of labor, subsistence needs, dispossession, slavery, consumer desire, patriarchy, white supremacy, neocolonialism, military repression, etc.	All of the above plus algorithmically-organized divisions of labor, platform connections and privileges, sensor implantation, inculcation of ‘digitization’ discipline among platform users, etc.
How is the necessary nonhuman ‘nature’ compelled, surveilled, disciplined and regimented?	Forcible resourcification, plantation organization, expansion of waste dumps, regulation, conservation management; institutionalized economics, etc.	All of the above plus centralized data collection via distributed sensors, training of nonhumans by humans and machines via algorithmically-organized crowdwork platforms, etc.
What are some characteristic spaces where workers are assembled?	Factory floor, office, bureau, warehouse, prison, other urban spaces; plantation; mine; farm, suburb or ring city, etc.	All of the above plus digital platforms spanning kitchens, thoroughfares, offices, sweatshops, prisons, refugee camps, etc.
What types of fatigue, debilitation, alienation or “maxing out” of workers and their commons arrangements are involved?	Deterioration of worker health, resilience and creativity; loss of soil fertility; accelerated entropy rates; loss of commons flexibility in response to ecological stresses; global warming; etc.	All of the above plus additional modes of creativity loss, e.g., lessened ability to navigate without GPS or program innovatively; accelerated climate change; etc.
What kind of contact, connection, accommodation and resistance among workers is involved?	Cooperation, humor and opposition on the factory floor; unionization; strikes; riots; threats; work to rule; foot-dragging; ‘wages for housework’ aimed at making reproductive work uneconomic, prison abolition movements, movements against white supremacy, etc.	All of the above plus platform-mediated contact, cooperation, resistance, boycott among dispersed or concentrated worker groups.

In explaining why interpretation machines, like power looms or automated blast furnaces, are structurally incapable of replacing living labour in capitalism, this article has also sought to discredit the notion that AI introduces fundamental novelties into capitalist relations. Insisting that AI needs to be grasped in terms of work – of capitalist mechanization and transformations surrounding nonequilibrium thermodynamic systems – it is implicitly critical, for instance, of claims that AI can jump-start a postcapitalist economy; reduce waste; save energy; offer a pathway to ‘luxury automated communism’ (Bastani, 2019); decentralize social relations; provide nonhumans with ‘autonomy’ (Seidler et al., 2016); promote Indigenous conceptions of territory or rights of nature; reconstitute nature conservation; carry out human-independent scientific research; or avoid capital’s perennial reliance on racism, colonialism, class hierarchy, patriarchy and ecological degradation. Rather than treating AI as a black box that can only be assessed after the fact for appropriate ‘applications’ or possible ‘implications,’ the article has attempted to open up for closer examination the structure of AI itself and its evolution out of previous industrial machine networks. It has suggested that, for critical popular movements, this inquiry must take firm priority over overhasty speculations about how AI might ultimately be best ‘governed’ or ‘regulated.’

By using a ‘de-Cartesianizing’ methodology to draw analogies between the labor that steps to the side of the standard 19th-century industrial machine and that which today steps to the side of AI, the article has attempted to provide a basis for discerning what genuine differences exist in the *ways* that the two sets of workers step to the side, as well as the genuine differences that exist between ‘digital natures’ and earlier industrial natures (see Table 3). If Marx gained greater understanding of the nature of living labor through his inquiries into the first industrial machines, so too, perhaps, can 21st-century critics, via inquiries into the new interpretation machine networks that constitute AI. The old AI of steam engine governors, Jacquard looms and ‘numerical control’ belonged to an age when capital was bent on extending the wage relation and the rule of the state worldwide (Huber, 2009; McMichael, 2015). It belonged to the age of factory mechanization of skills such as spinning, weaving and automaking. By contrast, the new AI of predictive algorithms and data centers belongs to an age when capital is compelled to try to push beyond the ‘inefficiencies’ of the wage, the welfare state, and the factory and its extended supporting ‘hidden abodes’ (Fraser, 2014) in unwaged care work, unenclosed commons, and so forth as dominant means of appropriating living human activity. This is an age of precarity, casualization, distributed micro-tasks, plummeting worker compensation, gutted welfare regulation, prison-industrial complexes (Gilmore, 2006), rust belts, and digital platforms extending the workplace into novel, increasingly far-flung regions (Jones, 2021; Neel, 2019): an age of financialization, fevered infrastructure and logistics expansion, and increased focus on value realization in speedy circulation and distribution as well as debt. While the old AI was an aid to attempts to mechanize adult skills of manufacturing and transport, the new AI aims more at mechanizing underlying toddler skills of recognizing, interpreting, inferring, understanding, wayfinding and the like. In doing so it must enlist new reservoirs of labor comparable to those that were needed to support conventional industrial development, to say nothing of the old AI devices that helped govern them. Felicitously, however, the new AI arrives on the scene not only relatively unencumbered in itself by the links with the atavistic wage demands associated with pre-neoliberal capitalism in the global North, but also ready to offer new tools to capital in its ongoing battle against the ‘inefficient’ wage in other sectors.

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