INTERPRETATION MACHINES

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Political struggles since the 19th century have repeatedly pushed left movements to seek footholds among the spiraling, ever-renewing contradictions of capitalist industrial mechanization and its relation to work and energy. Barely even begun by Karl Marx, one of their great pioneers, these investigations and experiments remain fragmentary and contested.[1] Yet the crises now being thrown up and exacerbated by 21st-century digital mechanization, even as they confront the left with fresh puzzles, may offer opportunities for shedding new light on this longer history of automation.

This essay sets out three lines of argument in response to these challenges. The first is that it may be more useful to movement organizing to stress continuities between industrial-era and digital-era value-creation than to focus only on differences. The second is that the contradiction between living and dead labour that Marx identified in the 19th century not only persists in the most intimate reaches of today's digital economy, but also remains fundamental both to understanding crisis and to identifying possibilities for radical political change. The third is that it may make more strategic sense for the left to approach the striking innovations in automation advanced over the past decade by the likes of Facebook, Google, Amazon, Baidu, Tencent, Alibaba, Microsoft and Apple as a new level of the *mechanization of interpretive work* than to acquiesce in mystifying labels such as *artificial intelligence* (AI).

Pace some theorists of 'cognitive capitalism', the contradiction between the 'dead knowledge of capital' represented in algorithms and computers and the 'living knowledge of labour' is not a '*new* form of antagonism' superseding the 'traditional opposition between dead labour and living labour inherent to industrial capitalism'.[2] It is, in essence, the same antagonism. In the 19th century, it would have been self-defeating for labour movements to have consented to the emerging fantasy that the process of division of labour combined with fossil fuel-powered mechanization represented the early stages of an asymptotic approach toward some hypothetical final state of capitalism in which all workers could be completely and forever 'deskilled', all human labour 'replaced', made 'redundant' and valueless and allowed to relax under benign machine supervision, and all knowledge 'transferred' into self-provisioning machines that might or might not remain under the control of the capitalists out of whose drive, ingenuity and self-discipline they had supposedly sprung. It would be equally self-defeating today for labour movements to go along with what Aaron Benanav dubs the 'new automation discourse, propounded by liberal, right-wing and left analysts alike', according to which 'we are on the verge of achieving a largely automated society, in which nearly all work will be performed by self-moving machines and intelligent computers' and humans can be put out to pasture while capitalism (or fully automated communism) rolls on.[3]

This is why it may be helpful from a left perspective to avoid the jargon of *artificial intelligence* in favour of the term *interpretation machine*.[4] Since Charles Babbage's time, the main jobs of the word 'intelligence' have been to conceal proletarian work, reinforce class, racial and gender divides, and justify social surveillance. Already in the 19th century, as historian Simon Schaffer makes clear, elite efforts 'to make machines look intelligent' were proceeding hand in hand with attempts to degrade and

render invisible the 'human skills which accompany them' – the 'labour force which surrounded and ran them' and constituted the 'sources of their power' – as well as with projects to build out the ideological edifice of orthodox economics.[5] The word 'artificial', meanwhile, carries much the same reactionary baggage as its antonym 'natural'. As logician Charles Sanders Peirce was already pointing out well over a century ago, it's never been possible to locate a 'faculty of discussion' or cognition in any 'natural' structures (brains, tongues, lips, lungs) that exclude 'artificial' ones (inkstands, pencils, alembics, typewriters, books, hand calculators, iPhones, neural nets) – or vice versa.[6] Insofar as there can be said to be such a thing, 'intelligence' has always been 'artificial'; conversely, any 'intelligence' *called* 'artificial' is likely in fact to be as 'natural' as it comes, insofar as it is useful at all. Encouraging a critical approach to 21st-century digital developments, the term 'interpretation machine' implicitly acknowledges these political and historical realities, whereas the phrase 'artificial intelligence' tends to hide them.

MECHANIZING INTERPRETATION

Capitalist labour, like any other kind of work, has always involved interpretation. It cannot but be thoroughly 'cognitive,' 'symbolic' and 'affective,' right down to the swing of the hammer of the most brutalized or 'deskilled' assembly-line drudge. Particular ability sets connoted by phrases like 'skilled labour,' 'mental work,' 'knowledge work,' 'symbolic analysis,' or 'immaterial labour' – whether the specialized, acquired fine judgement of machine tool operators or photocopy machine repairers or the creative theorizing of postdoc physicists and advertising executives – are never much more than a thin layer of icing on top of the vast multicoloured cake of everyday interpretive capacities brought into play in the actions not only of every so-called 'unskilled' worker doing the most 'manual' labour but also of nearly every human being over the age of five.[7]

Even more than any particular tasty icing, it's this larger cake, consisting of some of the 'deepest, most hard-won human capabilities',[8] that capital is now increasingly striving, in obedience to its contradictory imperatives, both to have and to eat. The following are a few interlinked examples of the generic interpretive skills in question:

- *Recognizing* new instances of old categories or exemplars: optical characters, images, faces, places, voices, retinas, sentences, intentions, emotions, preferences, paths, vistas, flows, diseases, sexual orientations, patterns of biological growth and so forth. This quotidian, skilled 'labour of perception'[9] is performed mostly unconsciously by every human being nearly every second of every day, whether for pay or not, requiring minimal training examples and minimal energy expenditure.
- *Translating*, a historically-constrained relationship-building skill whose power-laden, collective exercise gives rise to what come to be recognized at various moments as crystallized meanings and beliefs[10] (and ultimately, in the computer age, to the even more reified, specifically 20th-century artefacts of 'signals,' 'information,' 'instructions,' 'commands,' and 'communication').[11] While most colourfully displayed by multilingual individuals, this improvisatory work is also constantly done – typically without much thought being given to the matter – by anyone trying to understand others speaking the *same* language.[12]
- *Wayfinding*, another everyday 'reproductive' socionatural skill of orienting oneself and adjusting one's movements as one feels one's way along a path – a type of work essential to daily life, the acquisition of knowledge, commodity circulation and capital accumulation alike.[13]

- *Sensing, searching for and retrieving knowledge* as part of *learning* processes whose goals are mobile.
- *Remembering* as a skilled social activity undertaken in challenging times in order to 'articulate the past historically'[14] in ways that make it possible to find ways forward through uncertainty.
- *Calculating*, including the ability to recognize and interpret mathematical symbols, carry out mathematical procedures differently in different or unanticipated contexts, and decide appropriate levels of precision.[15]
- *Knowing how to follow a rule flexibly*, for example, knowing the difference between 'following a rule' in ways prescribed by capital and 'working to rule,' the familiar form of labour protest.
- *Understanding what questions to ask* in order to extend conversations, smooth relationships, clarify context, move past misunderstandings or fruitfully probe various unknowns. One example is the ability to find questions making it possible to decide whether it is appropriate in given circumstances to interpret unexpected utterances as reflecting strange beliefs and normal understandings of word-meanings or shared beliefs but unusual understandings of word-meanings.[16]
- *Anticipating* the likes, dislikes and decisions of others.
- *Intending* others with whom one is interacting to *recognize* one's intentions to produce responses, and for this recognition to be part of the reasons for the responses.[17]
- *Learning, building and exercising trust or respect* toward persons, institutions, nonhuman organisms and experimental apparatuses in the course of everyday practices of negotiating, caring, conducting financial transactions, hunting or doing science.[18]
- *Playing*, *teasing, joking, messing around, formulating metaphors or analogies*, and so on.[19]

None of these seemingly mundane activities in itself constitutes a 'trade' or 'occupation' in the usual senses used during the past 500 years (weaver, papermaker, midwife, bricklayer, scrivener, fitter, nurse, construction worker, cook, lorry driver, homemaker, musician, strawberry picker, computer programmer, chemist, logger, market analyst, office cleaner, lawyer). But they do form, in varying combinations, a necessary part of each of them. Indeed, it's the exercise of these abilities that, when assimilated into capital, arguably constitutes the core of the 'living labour' that Marx contrasted to the 'dead labour' crystallized in machines and repetitive mechanical procedures. Encapsulated by Ludwig Wittgenstein in a single gnomic phrase, 'knowing how to go on,'[20] they've always been essential across the board in making capital's rule sets, divisions of labour, machines and algorithms function as required to accumulate surplus.[21]

Since the industrial revolution, it has been a commonplace that one trade after another can be expected to be automated away over time (scrivener, longshoreman), while others can be expected to come into being (sewer cleaner, software engineer). Similarly, jobs may be mechanized out of existence in the US, say, only to be reincarnated in Indonesia or Viet Nam. Or women in Europe may leave the kitchen to take charge of expensive machines circulating shipping containers while cheap live-in nannies from the Philippines move in to help raise the children.[22] As Marx argued in volume 3 of *Capital*, however obvious it may seem to an individual capitalist that displacing or weakening one set of workers using mechanization is the 'immediate source of increasing profit', somewhere in the system injections of new living labour, whether in the form of old or new trades, will ultimately have to compensate if declines in the rate of profit are to be forestalled.[23] So relentless is this process of the 'reorganization of the organic composition of capital'[24] – the churning redistributions and augmentations of living labour across the world that allow surplus value to be drained from less

mechanized to more mechanized sectors – that the state has had to make it its business to help smooth over the disruptions that inevitably result for capital itself.

Perhaps the only thing new about this dynamic in the 21st century is the degree to which not only individual 'occupations' but also various aspects of the core of living labour itself are undergoing mechanization – inevitably paired, again, with surges in the recruitment of living human labour power at numerous points in the system. During the last decade in particular, almost every skill on the above list has, to a certain extent, been successfully automated:

- *Recognizing and classifying* (mechanized by, for example, facial, voice and character recognition software, 'sentiment detection' and 'opinion mining' devices and automated medical diagnosis technologies).[25]
- *Translating* (mechanized by Google Translate programmes that can simultaneously correlate, at blinding speeds, thousands of long strings of symbols in one language to 'equivalent' strings in another).
- *Wayfinding* (mechanized by Google Maps, GPS systems, driverless car technology and predictive analytics software that can shift the task of optimizing deliveries 'to algorithms rather than tribal employee knowledge').[26]
- *Searching for and retrieving knowledge* (mechanized by Google, Baidu or Bing digital string search engines, book digitization technologies and so forth).[27]
- *Remembering* (mechanized by software recognizing and sorting huge stores of digitized information from the past).
- *Calculating* (mechanized via speedy floating-point processors).
- *Following a rule flexibly* (mechanized through statistically-based machine learning programmes – for example spam filters – that progressively 'learn' from masses of human-labelled data rather than being programmed to match abstractions written out by experts).
- *Extending and fulfilling conversations by choosing the right questions to ask* (mechanized in, for example, automated personal assistants such as Alexa and Siri as well as the therapeutic program ELIZA as early as the 1970s).[28]
- *Intending* others with whom one is interacting to *recognize* one's intentions to produce responses, and for this recognition to be part of the reasons for the responses (ditto).
- *Anticipating* the likes, dislikes and decisions of others (mechanized through predictive algorithms that identify what books, movies or political propaganda various populations are likely to appreciate).
- *Building trust relations among humans in bulk and at high speeds* in order to cut transaction costs associated with traditional 'trusted intermediaries' such as lawyers, bankers, state guarantors and so forth (mechanized using computer-intensive cryptographic and 'distributed ledger' technologies including blockchain, Bitcoin, and 'smart contracts' automating the human interpretive work traditionally necessary for contracts, private property and commercial transactions and collapsing contract drafting, execution, payment, settlement and enforcement into a single activity).[29]
- *Interpreting and enforcing welfare, labour and credit law* (mechanized using computer systems such as India's Aadhaar system, which automatically determines citizens' entitlements using stores of biometric and demographic data, or China's reputation-scoring system).
- *Building and exercising trust among scientists and their apparatuses* (mechanized via scientific discovery machines such as BACON).[30]

- *Building and practicing respect between human and nonhuman beings* (mechanized through artificial intelligences grafted onto agricultural fields, forests and animals to monitor and care for them, a la 'precision' or 'digital' agriculture and 'self-owning forests').[31]
- *Playing*, *teasing*, *messing around*, *formulating metaphors* and so forth (mechanized via, for example, care-home or therapeutic robots such as Pepper, Chapit or Zora; prospective sex robots; champion chess or Go programmes such as AlphaZero; or software for producing art works).[32]

This new wave of automation has been facilitated by an unprecedented 'perfect storm' bringing together three technical advances into a powerful synergistic package. One is 'deep learning' software that can continuously teach itself what algorithms or recipes are best at predicting whatever it wants to predict, assuming it is fed enough data (a newfangled instance of 'machines making machines'). Another is computerized public surveillance, Application Programming Interfaces, CAPTCHAS (Completely Automated Public Turing Tests to Tell Computers and Humans Apart), online quizzes, and other labour capture mechanisms for the construction and continuous augmentation of the requisite enormous libraries or stocks of digitized bits of information out of undigitized flows of human culture – for example, labeled and encoded JPEG images or sentence and sentence-pairs coded as series of ones and zeros. Included are devices through which image-recognition software or Google Translate parasitize the voluntary, almost unconscious linguistic work of hundreds of millions of smartphone owners exchanging gossip or snapshots on Facebook or other platforms. A third ingredient is the big increases in computer processing speed and capacity that make it possible to use deep learning algorithms to convert these growing mountains of 'big data' into cheap, accurate, micro-targeted predictions in breathtakingly short times, as well as carry out the advanced cryptographic operations necessary for automated-trust electronic currencies like Bitcoin.

This trifecta of innovations has helped reawaken ambitions to automate not just this or that particular occupation, and not just this or that specialized interpretive skill, but living labour as such, to the extent that computer science prophets like Andrew Ng of Baidu and Stanford refer to AI as 'the new electricity', while *The Economist* sees digitized data as 'the new oil'.[33] Interpretation machines are being groomed both as a new 'infrastructure' that will eventually become a taken-for-granted background of enhanced capitalist activity across the globe and as a separate economic sector that can be hived off from others, much as an 'energy sector' was hived off in the 20th century. Transcending garden-variety automation that takes place piecemeal in specific industries, interpretation machines are seen as capable of making ineluctable inroads into white-collar, blue-collar, pink-collar and no-collar employment across the board.[34] Trust machines, for example, in the eyes of libertarian techno-visionaries like Nick Szabo and the shadowy blockchain inventor known as Satoshi Nakamoto, could drastically reduce capital's need not only for bankers and lawyers but also for courts, regulators, notaries public, auditors, registrars, portfolio managers, real estate agents, shipping clerks, credit scorers, insurers, police, and whole layers of the accounting, and nature conservation professions and much of the state itself, slashing transaction costs everywhere.[35] Combined with search engines, they could eliminate whole layers of human-infested back-office operations and make it economical to register, privatize, monetize and make globally visible and exchangeable the tiniest and most exotic bits of property, ranging from the natural germicide produced by a species of Amazon frog to the informally-held rights to half a hectare of a slum settlement in Kenya or the individual debt of a street seller in Mumbai. Through automated verification and settlement, it could also speed up the transfer of goods through global trade corridors spanning numerous frontiers. At the same time, machines recognizing changes in risk information worldwide could feed data into millions of automatically self-

adjusting individual smart insurance contracts in real time, supposedly 'rationalizing' and reducing underwriting firms' exposure to high-risk customers. Wayfinding machines, in addition, could automate away the labour of lorry and delivery drivers as well as a range of logistics and transport workers of other kinds.

Intensified mechanization of recognition, search, anticipation and wayfinding also opens up possibilities of further automating what Ursula Huws and others have identified as 'consumption labour'.[36] Once shoppers' constituent skills of recognizing needs, browsing, interpreting and responding to advertisements, evaluating products for their suitability, ordering, paying and finding their way homeward are broken down and the divided labour duly farmed out to interpretation devices, consumers can be mechanized into tens of millions of 'virtual yous'[37] that are sold to corporations. Machines capable of simultaneously forecasting the reactions to specific commodities of that many separate individuals accurately and cheaply enough would be able not just to suggest items for a customer's consideration – as already happens – but also to ship them to her before she has ordered them without much risk of their being angrily returned. That would uncover and eliminate one more impediment to high-velocity circulation. Interpretation machines can also partially automate 'prosumption' labour – the unpaid, informal work of consumers or voters who volunteer feedback, personal data, design ideas, reviews and geographical knowledge to corporations in ways that benefit their production, sales and circulation strategies.

THE OLD IN THE NEW

It's easy to be dazzled by the scale and scope of such efforts to mechanize the most generic forms of living labour into dead labour crystallized into amalgams of giant data centres, neural network software, global fibre and satellite links and smartphones and other worldwide sensors by the billions. But as capital leans into its 'informational' turn, powered by massive state involvement, it's crucial to be clear that it isn't leaving any of its fundamental contradictions behind. As Dan Schiller observes, the 'specificity of digital capitalism' needs to be set '*within* abiding structural trends and historical crisis tendencies rather than in a putative break with them or an evolution out of them'.[38]

First, it should be noted in passing that there's nothing new about the mechanization of interpretation as such, but only about the extent, speed and stealth of its advances over the past 10 years or so. For centuries, capital has been isolating and automating one or another of the smaller interpretive skills embedded in labour and the physical tools and devices attached to it, partly to reduce its vulnerability to small groups of workers in command of big or dangerous machines. From the mid-18th century, mechanical steam engine 'governors' were devised to 'recognize' and regulate the speed of steam flow as no human mediator could, helping to inaugurate an era of the machine as an 'infomechanical relay between flows of energy and information'.[39] Steam power in turn made it possible for other devices such as textile machines to 'categorize,' 'measure' and respond to variations in their own inputs with superhuman rapidity. Thermostats (or what the 19th-century prophet of labour control Andrew Ure, one of their developers, called 'heat governors')[40] could 'sense' more accurately than any human how hot something was, and 'communicate' their findings more quickly to furnaces or boilers schooled in how to 'read' them. Nineteenth-century Jacquard looms using punched cards to mechanize the craft of human silk weavers rapidly 'translated' symbol types into one another, speeding up production of luxury cloth 24 times and undercutting workers' bargaining power.[41] Similar interpretation skills were later automated in census machines, artillery targeting systems, 'numerical

control' for machine tools, and word processors and DVD players. Twentieth-century autopilots were meanwhile 'taught' to 'observe' and modify aircraft responses faster than any human pilot could.

Second, today's interpretation machines follow closely the pattern of older industrial machines in that they make little pretence of doing just what their human 'models' do. Strictly speaking, they don't duplicate skills. Instead, they identify, isolate, and activate facsimiles of particular *fragments* of human action, amplifying and reproducing them repetitively at high speeds in order to produce uniform outputs in bulk, using an omnibus 'energy' organized by thermodynamics. The golem or witch's apprentice thus created then in turn has to be treated to constant, meticulous oversight by humans employing other skills – including care and cleaning skills – in order to produce, preserve or circulate surplus value. Capacities to perform this new work also tend to be devalued and degraded as further frontiers of capitalist renewal are sought.

For example, the 19th-century spinning machine was never designed to do everything that a human spinner did when she was spinning – improvise on certain learned routines of eye, finger, thread, wood and arm; keep in mind the needs of the market or the home; be sociable; sustain a family or community; and so on. It did something much more limited and rigidly repetitive. What it did was also physically more dangerous, insofar as it was driven by quantities of force that the individual artisan wouldn't have known what to do with, and that required the thoroughgoing reorganization of landscapes to extract and transport machine-ready energy before transforming it, via manufacturing, into unusable waste forms. The spinning machine's human tenders, in turn, had to alter the use of their own interpretive abilities in order to adapt to the simple, accelerated rhythms of the whole assemblage and keep the high-powered contraption running, drawing on reserves of resilience that were often quickly worn out.

By the same token, what a 21st-century interpretation machine such as Google Translate does results in an output of sentences, but is not the 'same thing' that human interpreters do. Instead, via the internet, Google Translate gloms onto billions of digitized data strings representing sentences – products of oceans of the living work of past and present generations of humans and nonhumans. It then subjects this 'big data' to computer operations that are even more endlessly repetitive than the spinning machine's in order to mass-produce cheap predictions – probabilistically rather than linguistically[42] – about which sentence-to-sentence equivalences would likely be most acceptable to human translators, especially those working in international business. And it constantly corrects its own procedures on the basis of new digitizations provided free of charge by users of electronic devices around the world. Facebook's own 'prediction engine', meanwhile, 'ingests trillions of data points every day, trains thousands of models – either offline or in real time – and then deploys them to the server fleet for live predictions'. In 2018, Facebook's assembly line manufactured more than six million of these 'prediction products' per second, or over 189 trillion saleable commodities per fiscal year.[43] Again, such interpretation machines do not do – and are not intended to do – what, say, human planners do when trying to foresee the future. For one thing, they produce a much greater number of predictions. They transform past living labour into a frozen or 'dead' form much more quickly, extensively and accurately than any division of labour using manual rule sets. Their predictions are also generally better than any human's prediction of his or her own behaviour. In addition, they are capable of surprising observers with leaps that look 'unprogrammed', as both Charles Babbage and Alan Turing had already demonstrated in their day.[44] But they also do not exercise the Wittgensteinian skill of 'going on' that is one distinguishing feature of living labour – a difference that becomes painfully obvious when they go into a 'tailspin' owing to unexpected events such as the Covid-19 pandemic.[45]

Google Translate's relationship to thermodynamic energy is also similar to that of the spinning machine. With its giant, publicly-subsidized server centres, transmission networks and big data-trained natural language processing models, Google Translate too needs quantities of electricity that human interpreters wouldn't know what to do with, again demanding professional management of humans and nature in fossil-fuel extraction zones.[46] Overall, digital energy consumption is growing by about nine per cent annually worldwide, with the carbon emissions of blockchain 'trust machines' alone already on the order of those of a medium-sized country;[47] the energy cost of a single blockchain transaction mediated by the leading firm Ethereum was reported in April 2019 to be 35,000 watt-hours, compared to the less-mechanized Visa figure of 1.69 watt-hours.[48] Partly as a result, interpretation machines' proliferating wastes, like the wastes of 19th-century industry, call for further armies of compensated and uncompensated human and nonhuman cleanup workers that were simply not required for the work of human spinners or translators.[49] Over time, these workers too can be expected to 'wear out', in the sense that, for whatever reason, they can no longer deliver the services capital requires cheaply enough.[50] As with the spinning machine, there is no activity that stays constant through the process of 'being mechanized'; indeed, the whole world is changed.

These parallels need some sharpening. The capitalist process of splitting up human activity and energizing stereotyped repetitions of the fragments – visible in both the spinning machine and in Google Translate – did not emerge out of nowhere. For Charles Babbage, the inventor of the Analytical Engine and one of artificial intelligence's 19th-century grandparents, industrial machines were just a way of carrying forward the earlier mission of divisions of labour. This was to decompose the integral ability sets embodied in craftspeople, particularly those with what Babbage called 'higher' or 'mental' skills, into 'simpler', dumber, more quantifiable, surveillable and supervisable components. The advantages were multiple. Measurable quantities of purchasable task could be precipitated out of the amorphous labour power confronting the capitalist. Bosses could more easily avoid paying for anything in excess of the 'precise quantity' of 'skill or force' that they deemed necessary for any manufacturing process that it was their prerogative to identify, describe and subdivide. The costs and lost time of apprenticeship could be reduced. The supply of workers competing for the less 'skilled' jobs that resulted could be increased, making them cheaper and more replaceable and dispensible. Opaque webs of relationships and duties among the workforce could be transformed, simplified and redistributed along the lines of a hub-spoke structure, with 'master manufacturers' at the disciplinary centre – a profit-panopticon linkage that was later developed in a very different way in 'dataveillance' or what Shoshana Zuboff calls 'surveillance capitalism'.[51] As far as possible, 'intelligence' and its ownership could be centralized in the same way, as Taylorism and managerialism continued to attempt to do in the 20th century. Each fragment of the split-up activities could then supposedly be replaced by machine motions, moderating the possible increase in demand for the augmented supply of 'unskilled' labour and further sharpening the distinction between bosses at the centre and workers around the periphery.[52] The machine would become, in the words of Babbage's brilliant colleague Ada Lovelace, 'the being which executes the conceptions of intelligence'[53] possessed by the master. It would 'consign class struggle on the shop floor to the rank of an unscientific superstition', as Caffentzis paraphrases Andrew Ure.[54] Surplus value could be conceptualized as flowing from machines that were the product of capital's own digitized intelligence combined with steam power, rather than from the uncompensated exercise of workers' biologically- and socially-evolved ability to 'go on' in a nonmechanical fashion on the basis of just a few examples.

Marx, Babbage's 'most penetrating London reader',[55] understood that this fantasy about how surplus was produced had already restructured much of Victorian reality. Accordingly, he put in a lot of effort to 'traverse' it, to borrow the Lacanian term.[56] Marx acknowledged that the productive move from combinations of *trades* (along with various trades' tools) to combinations of centralizable *processes* (along with industrial machines) increased the 'number of workers who [could] be exploited simultaneously using the same capital' and reduced the labour time necessary for the reproduction of labour power, in effect again cutting the wage bill, undermining workers' bargaining power and independence, and freeing up capital for other uses. But he also took care to emphasize that the new mechanized hub-spoke structure was not static but dynamic, and was irremediably rent by contradiction. The 'surplus population' of living labour generated by machinery did not simply increase linearly and without limit in proportion to the spread of machinery. Machinery itself was dynamic – if it 'continually casts out adult workers', he said, it also 'needs to expand continuously … in order merely to "re-absorb" them, to draw them back in'.[57] The mechanized 'transformation of guild masters and their journeymen into capitalists and wage labourers', Marx added, should not be confused with a universal, long-term 'displacement of the wage labourers themselves by the application of capital and scientific knowledge'.[58] More machines and the associated tendency of the rate of profit to fall intermittently pushed capital toward renewed demands for masses of living (including reproductive) labour in one or another zone of the system, via the transformation of value into price,[59] regardless of how capital construed labour's 'skill' and 'intelligence'.

It's here that the non-incidental role of thermodynamics in the capitalist projects of both the 19th and the 21st centuries needs to be re-emphasized. As Marx noted, it was the growth of the division of labour that invited a 'mightier moving power than that of man', not the other way around. That 'moving power' – a generic, superhuman force making possible the widespread and extremely regular repetition, at extremely high speeds, of the stereotyped, 'dumb' subroutines of human action that divisions of labour had already split apart and made more measurable, predictable and disciplinable – took the form of the new, commensurated 'energy' that emerged in the late 18th and 19th centuries. This new 'energy' – organized by thermodynamics and virtually synonymous with a systematic, productive reorganization of landscapes around a logic of degradation[60] – was essential in turn in enabling capital to subject the skills of still more enclosure-dispossessed workers, whose labour-power could now be easily bought by property-owners, to centralized disassembly, reorganization and control, facilitating 'combined labour' (or what Marx somewhat confusingly called 'simple cooperation') on ever more populous factory floors.[61] Just as a complete visualization of the spinning machine would have to take in not only children dodging in and out among its rapidly-rotating bobbins and cotton plantation slaves lifting hoes, but also coal miners crouching in countless stuffy underground chambers, so too a complete visualization of today's interpretation machine would need to encompass not only data centre staff replacing tensor processing units and DRC miners enduring abuse, but also interruptions to the flows of major rivers worldwide.[62]

One confirmation of the enduring nature of these features of capitalist mechanization is that the scare quotes around those intentional verbs that were used above to describe 19th-century thermostats or steam engine governors ('recognize', 'translate', 'measure', 'know') evidently need to be kept firmly in place when describing what 21st-century interpretation machines do. It may be true that early AI critics like Hubert Dreyfus and John Haugeland turned out to be completely wrong to suggest that a computer could never beat a world chess champion, make a transcendently original move in the game of Go, or deliver a beautifully balanced translation of a page of Proustian prose.[63] It is also true, conversely, that AI visionaries like Demis Hassabis of Google's DeepMind or Robert Mercer, the

machine translation pioneer who became a billionaire hedge fund manager and financier of the Donald Trump and Brexit campaigns, turned out to be absolutely right in seeing the future of interpretation devices not in attempts to encode the experience of experts into machines,[64] nor in getting machines to work just like the human mind, but rather in letting artificial neural networks 'do it their way'[65] via incessant, energy-intensive crunching of gigantic masses of data that (the chess and Go examples perhaps excepted) are continually produced by labour-intensive processes carried out all over the world. But neither the incidental failures of vision of the likes of Dreyfus or Haugeland nor the triumphs of the likes of Hassabis or Mercer changes the reality that the prospect of 'replacing' living human labour in the process of capital accumulation – and thereby removing the contradiction that Marx identified between living and dead labour – remains so distant that it is virtually irrelevant to foreseeable strategies of anticapitalist resistance. Successful machine simulations of various isolated fragments or manifestations of human interpretive skills – ranging from putting a name to a face to competing at Jeopardy at championship level – have only highlighted the fact that a working facsimile of what is called artificial *general* intelligence (AGI) – or even just a machine that could hold up its end of a wide-ranging conversation, convincingly reproduce the performance of a single neuron, sustain what David Graeber calls the 'baseline communism' that underpins worker coordination,[66] or participate in Marx's 'simple cooperation' – is still a very long way off. So far, the capabilities of interpretation machines are not all that much less 'bitty' than those of the old steam engine governors; the contrast isn't as marked as it may look between the 19th-century spinning machine, which could only wastefully repeat one stereotyped shard of past human actions again and again, and the deep learning-trained Alexa robot.

INTERPRETIVE LABOUR TODAY

The upshot is that so-called artificial intelligence isn't any closer to making living labour obsolete than 19th-century industrial machines were. Nor was that ever the point of either mechanization movement, no matter how loudly capitalist ideologists might occasionally assert the contrary. Capital doesn't really need, and probably couldn't afford, machinic labourers that perform the functions of well-rounded, versatile interpreters.[67] It can already get plenty of the human variety at bargain prices. Thus computer scientist Hamid R. Ekbia and anthropologist Bonnie Nardi compile evidence showing that recent artificial intelligence advances, instead of representing an incremental step toward full automation, exemplify a more complex strategy of *heteromation*, or 'extraction of economic value from low-cost or free labor in computer-mediated networks' so dispersed and anonymizing that workers can be 'treated as nonpersons' – one more wheeze devised by capital for coping with the tendency of the rate of profit to fall.[68] 'Automation vs. human labour is a false dichotomy', affirm Microsoft's Mary L. Gray and Siddharth Suri in a comparative study of how Silicon Valley's new, supposedly 'intelligent' devices require the incessant 'ghost work' of millions of human assistants that remain a good deal shrewder in most respects.[69] Sociologist Harry Collins, an acute longtime student of grassroots technical practice, reckons that a machine of 'human-like intelligence' is simply not on the cards 'unless it is fully embedded in normal human society' in a way that is unlikely to be the 'result of incremental progress based on current techniques'.[70] Even Geoffrey Hinton, the revered computer scientist known as the 'godfather of deep learning,' who clings stubbornly to the idea that 'unsupervised' machine learning free of inputs from living human labour will someday become possible,[71] no longer believes that 'true' AI can be achieved by continuing to develop current energy- and data-intensive simulation techniques.[72]

In what ways, exactly, do 21st-century interpretation machines, like 19th-century industrial machines, function merely to redistribute, transform and extend the exploitation of living labour rather than progressively eliminate it? It is not merely that incessant human interpretive work continues to be fundamental for Graeber's 'baseline communism' among workers – that cooperative, empathetic interaction without which no office or supply chain could operate.[73] It is not merely that it continues to be essential for the automation-resistant unpaid care and reproductive labour that has always propped up industrial capital;[74] or for the 'reading of the land' practiced by nearly all farmers; or for the thinking that 'solves new problems for which there are no routine solutions'; or for the type of communication that involves 'persuading, explaining, and in other ways conveying a particular interpretation of information'.[75] Nor is it only that the same type of activity is central to the performance of the satellite armies of pieceworkers, outworkers or contract labourers that have historically finished by hand in their homes what machines and their human attendants within factory walls could not accomplish, or could not accomplish cheaply enough;[76] or indispensible in what Marx called the 'intermediary' or 'preliminary' work tending the colonial plantations or running the mines extracting the masses of raw materials that such factories have so voraciously consumed.[77]

It is also that creative, living interpretive labour continues to be fundamental to the minute-to-minute and week-to-week productive actions of specific machines themselves. Nineteenth-century spinning jennies required 'both mental and physical finesse' from the child workers 'deftly moving from one heavily vibrating machine to the next' to reach their hands between moving spools to clear debris.[78] Locomotives demanded complex recognition, interaction and wayfinding skills from every individual in the teams of labourers charged with cleaning them out and keeping them running. In order to be able to reorganize, dismantle, and mechanize trade skills with any success via divisions of labour and fossil-fuelled heat engines, capital has always needed, at the same time, to harness more and more of this *unmechanized* interpretive labour. Even at the level of their most minute motions, industrial machines would have simply broken down or gone feral, rendering them useless to capital, had they not constantly been supplied with large local and distant injections of fresh living labour to mind the controls, improvise interfaces, do repairs, deal with unpredictable events, manage updates, recognize and absorb wastes, undertake cleanups, manage emergency shutdowns, cope with accidents, digitize and de-digitize, tend raw material flows, meet with bankers, enforce racial and gender divides and so forth. The more machines capital enlisted, the more workers it needed that were *not* machines. The more dead labour it had on hand, the more living labour it required.

So, too, the 21st-century artificial intelligence systems that make possible Facebook or Uber phone apps are dependent on an 'always-on labour pool' – accessible via the online application programming interfaces of on-demand 'microwork' labour market platforms such as Amazon's Mechanical Turk – to provide human input to censor texts, update image databases, double-check photo IDs and so on.[79] The Clearview facial recognition machine couldn't work without the unsung, unpaid work of humans labeling billions of images on the Internet in return for networking privileges.[80] Putatively fully-automated, blockchain-based 'smart contracts' turn out to require volumes of the creative human work of observation and legal interpretation if they are not to implode,[81] while the PARO robot (shaped like a cuddly baby harp seal), which cost US$15 million to develop, requires constant help from humans, both staff and patients, if it is to have a chance of effectively doing its job mechanizing care of dementia sufferers in homes for the elderly.[82] Facebook's algorithms for manufacturing saleable predictions designed to cut circulation time by increasing click-through rates for targeted advertising – no matter how many tens of thousands of servers stacked in giant refrigerated data centres are enlisted to execute them – would meanwhile grind to a halt without the billions of

hours of human interpretation work done by its users every day when they like, comment, scroll through status updates or merely find their way from one neighbourhood to another.[83] While Facebook currently has around 48,000 workers who have signed conventional labour contracts in exchange for wages, it can also tap the labour of more than 2.6 billion users who have consented to terms of service according to which their routine, living data-processing labour is swapped for platform interaction services. No surprise, then, that the market capitalization/workforce ratio at Facebook is US$20.5 million per paid employee, compared to General Motors' figure of $231,000.[84] Whatever the century, interpretive skills continue to make up the common core of living labour under capitalism.

The main difference between the two centuries in this respect is that, thanks to those 'deep learning' algorithms, fast processors, and advanced surveillance technologies combined with cheap thermodynamic energy, capital can now collect directly, and on a daily basis, many more of the quintillions of tiny moments of the exercise of the integrated interpretive skills that the global human population acquired as babies and young children, and, by transforming them into big data, add them to the 'elements of profit' that Marx wrote of in the first volume of *Capital* more than 150 years ago. (Quite suddenly it has become possible for capitalists to view conventional trust-building work, say, as 'slow' and 'inefficient', a perceptible 'fetter' or 'bottleneck' in production, circulation and consumption.) Just as thermodynamically-energized industrial machines helped spread the wage labour relation across the world beginning in the 19th century,[85] so 21st-century interpretation machines are enabling and necessitating recruitment not only of more wage work but also of the deeper regions of unpaid human labour. What the *Wall Street Journal* was already hailing in 2012 as 'largest unpaid workforce in history'[86] practices no single occupation, but must be on the job at all times if Jeff Bezos, Eric Schmidt and Jack Ma are to continue to get richer. In a more thoroughgoing and fine-grained way than it could achieve merely via the continuing reorganization, exploitation and degradation of thin layers of apprenticeship-inculcated trade skills, capital is now able to feed directly from the bigger cake of billions of 'lifetime[s] of being a human person from infancy on: of memories that begin in childhood, … of the development of habits of observation, compassion, empathy and sympathy'[87], and much, much more. As clearly as in the 19th century, the 'preservation and thus also the reproduction of the value of products of past labour is *only* the result of their contact with living labour'.[88]

One often-overlooked type of living human labour sustaining the 21st-century wave of mechanization of interpretation is the labour of making this labour itself invisible. This 'invisibilization' work is not confined to the tasks that IT ideologues continue to perform in denigrating the skills of women, colonized peoples, the working class, or ordinary humans generally. What poses a special challenge to labour movements is that this invisibilization work is also done by those humans themselves as, minute by minute, they voluntarily attribute their ability to perform living labour to machines.[89] Already in the 19th century, Marx had noted that industrial capital required that workers be placed in a situation in which they ended up crediting industrial machines with the 'intellectual faculties' of the workers themselves. This business model is being greatly augmented today with the spread of advanced interpretation machines. Thus in the 1980s, as sociologist Harry Collins notes, when cheap pocket calculators 'multiplied' 7/11 by 11 and 'deduced' the answer to be 6.9999996, their human operators would reflexively reinterpret the result as 7 – yet still assume that the machine was doing all the work.[90] In 2017, users of automated Google directions across irregularly laid-out cities did the same when the machines confronted crossings where streets jog slightly before continuing along slightly different lines. Google tended to tell users to 'turn' on the cross street and continue for a couple of metres, and then 'turn' back to rejoin the street that they had in fact never left. Users had to put in a bit of impromptu but unacknowledged interpretation work to 'correct' what was then the machine's

difficulty in simulating understanding of open-ended concepts like *turn* and *just go straight through the intersection*. (Any such 'bug' can in principle be eliminated with the application of more data, more algorithms and more energy, of course, but new bugs will then inevitably pop up to take their place.) By the same token, talk about 'driverless' cars typically ignores the fact that their development has been highly dependent on the labour-intensive 'reconstruction of Mountain View, California to be a safe place for these vehicles to navigate', to quote one artificial intelligence expert.[91] Similarly, an automated banking service reaching out to millions of poorer clients in Brazil turned out to rely on the streetcorner merchants who mediated between them and the system's computer terminals, and whose low- or zero-cost everyday interpretive labour in collaboration with customers vanished into 'software' in the eyes of central managers.[92] In such examples, only the computation is visible as, to adapt Marx's words, 'the human steps to the side'.

As Collins observes, computer and cellphone interfaces are not there to get rid of this kind of living labour. They are there to hide it, by finding mechanical means for exploiting only the most everyday, unthinking interpretive skills that nearly everybody possesses. In helping to make users unaware of the growing unwaged living labour they're putting into their dealings with interpretation machines, well-engineered interfaces such as Windows, computer mice, internet browsers and predictive text carry forward the capitalist mission of keeping uncompensated living work out of sight while burnishing the fetish of the self-running machine and the 'full automation' ideology that claims that machines are on an asymptotic approach toward 'replacing' humans in capital accumulation. Like the 19th-century factory, artificial intelligence interfaces constitute an apparatus to keep workers 'ignorant of the secret springs which [regulate] the machine and to repress the general powers of their minds' so 'that the fruits of their own labors [are] by a hundred contrivances taken away from them'.[93] As Jason W. Moore has pithily put it, 'the condition that some work is valued is that most work is not'.[94]

Yet human workers, as George Caffentzis writes, 'can always kill capital in its most embodied and vulnerable form: the machine'.[95] Needing, seeking and often creating forces that it cannot quite control and commons that it encloses at its peril, capital can never keep the tools of its repeated undoings entirely away from the hands of its resisters. That is as much a part of the politics of the new interpretation machines as it is of the politics of the old industrial ones. If risks of rapid depreciation are not recognized, IT firms' investment in the constant capital of (for example) server centres, big data storage, fibre lines, ensor processing units and deep learning architectures can become the 'source of an enormous dis-accumulation'.[96]

What are the specific contradictions afflicting interpretation mechanization and how might a historical perspective help popular movements work on them from the inside? Some contradictions are obvious and primary. One of them stems from the fact that capital's new interpretation machines inevitably reinforce its much longer-standing assaults on the life conditions of the world majority: their soils, their water, their relationships with plants and animals, their abilities to evade state surveillance and repression and regenerate commons. The poisonous symbiosis between interpretation mechanization and unsustainable energy and mineral development, for example, is coming up against growing revolts in 'sacrifice zones' of extraction and infrastructure development, whose inhabitants may well not be especially exercised about the specific exploitation of 'ghost workers' tending interpretation machines. So, too, the frontiers of 'iSlave' labour required to operate profitable IT hardware assembly zones can be expected to recede further, precipitating other crises. Then there are the repressed demands that occasionally burst out as the flip side of capital's efforts to invisibilize new

stretches of living labour, as well as already-visible reactions against the increasingly-mechanized surveillance that forms a part of business, military and bureaucratic plans alike – all evolving together with capital's obligatory displacement efforts.

Some contradictions may be more obscure, for example that between capital's perennial need for living Wittgensteinian skills of being able to 'go on' and its simultaneous assault on them via interpretation mechanization. As Shoshana Zuboff has documented, surveillance capital finds itself in a constant race to improve what she aptly calls its 'prediction products' – in her words, to make 'prediction approximate observation' more and more closely.[97] That entails widening and diversifying the digital architectures through which surplus from the worldwide exercise of Wittgensteinian abilities is extracted, unconsciously aiming at the contradictory 'ideal' of engineering that working public itself to the point of becoming so machine-like that the surplus dries up. The process is analogous to the one James C. Scott famously describes in *Seeing like a State*, in which a forestry science bent on extracting the maximum sedimented biological and social energies from trees moves from classifying and quantifying the diverse contents of existing forests more precisely and extensively to actively engineering them into predictable monoculture rows, with the result that the energies of the soil and the trees themselves become depleted and predictability blows up.[98] This type of contradictory dynamic, during which human actions and capacities are never stable, waiting around for machines to mimic them, but are constantly undergoing changes themselves, complicates political strategizing in the current moment. What happens to Mountain View as it is re-engineered to make its 'autonomous vehicles' look more autonomous? What happens to the law when, as Lauren Henry Scholz puts it, so many 'algorithms are introduced in institutional decision-making' that 'individuals outsource their valuation processes' to them?[99] When machines pump out millions of individually-tailored Trump memes to audiences that – for a time – respond by becoming more uniform, isolated and predictable? When programming skills themselves erode as, increasingly, software makes software? When capital's 'metric fixation' becomes turbocharged to the point that counterproductive tendencies become overwhelming?[100]

Which contradictions will bite, and when, how, and where, remains to some extent an open question. There are, moreover, some intrinsic counter-resistance characteristics almost baked into interpretation mechanization: the near-effortlessness of much of the interpretation work harvested by the big IT firms, which 'comes naturally' to almost all human adults; the resulting, almost 'built-in' invisibility of the work and the ease with which workers themselves attribute it to machines; as well as the extreme global dispersal of the workforce tending interpretation machines. Any serious evaluation of the future of resistance, however, is likely to need to take careful account of how today's interpretation machines fit into capital's longer history.

NOTES

I am grateful for comments and suggestions from Hendro Sangkoyo, Soumitra Ghosh, Leo Panitch and Greg Albo.

[1] For recent positive steps forward, see, for example, George Caffentzis, *In Letters of Blood and Fire: Work, Machines and the Crisis of Capitalism*, Oakland: PM Press, 2013; Andreas Malm, *Fossil Capital: The Rise of Steam Power and the Roots of Global Warming*, London: Verso, 2016; Matthew Huber, 'Energizing Historical Materialism: Fossil Fuels, Space and the Capitalist Mode of Production', *Geoforum*, 40 (1), 2009, pp. 105-115; Cara New Daggett, *The Birth of Energy: Fossil Fuels, Thermodynamics and the Politics of Work*, Durham: Duke University Press, 2019; and Alf Hornborg, *The Power of the Machine: Global Inequalities of Economy, Technology and Environment*, Lanham, MD: AltaMira, 2001.

[2] Carlo Vercellone, 'The Hypothesis of Cognitive Capitalism', paper presented at Historical Materialism Annual Conference, Birkbeck College and SOAS, London, 4-5 November 2005, p. 10, emphasis added.

[3] Aaron Benanav, 'Automation and the Future of Work – 2', *New Left Review*, 120(Nov/Dec), 2019, pp. 117-146, p. 117; 'Automation and the Future of Work – 1', *New Left Review*, 119, September/October 2019, pp. 5-38, p. 6. Among such theorists, whose genealogy stretches from characters in Dostoyevsky and Samuel Butler to John Maynard Keynes through 1950s and 1960s artificial intelligence pioneers such as John McCarthy, Herbert Simon and Allen Newell, are Aaron Bastani, *Fully Automated Luxury Communism: A Manifesto*, Verso: London, 2019; John Danaher, *Automation and Utopia: Human Flourishing in a World without Work*, Cambridge, MA: Harvard University Press, 2019; Daniel Susskind, *A World without Work: Technology, Automation and How We Should Respond*, London: Penguin, 2020; Pedro Domingos, *The Master Algorithm,* New York: Basic, 2015; Martin Ford, *Rise of the Robots: Technology and the Threat of a Jobless Future*, New York: Basic Books, 2015; Nick Srnicek and Alex Williams, *Inventing the Future: Postcapitalism and a World Without Work*, London and New York 2015; Nick Dyer-Witheford et al., *Inhuman Power: Artificial Intelligence and the Future of Capitalism*, Pluto Books: London, 2019; Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies*, Norton: New York, 2014; Paul Mason, *Postcapitalism: A Guide to Our Future*, London: Penguin, 2015; Andrew Yang, *The War on Normal People: The Truth About America's Disappearing Jobs and Why Universal Basic Income Is Our Future*, New York: Hachette, 2018; Nick Bostrom, *Superintelligence,* Oxford: Oxford University Press, 2014; Andy Stern, *Raising the Floor: How a Universal Basic Income Can Renew Our Economy and Rebuild the American Dream*, New York: Hachette, 2016; Peter Frase, *Four Futures: Life After Capitalism*, London: Verso, 2016; Ray Kurzweil, *The Singularity is Near*, New York: Viking, 2005; and Vitalik Buterin, 'DAOs, DACs, DAs and More: An Incomplete Terminology Guide', Ethereum blog, 2014, https://blog.ethereum.org/2014/05/06/daos-dacs-das-and-more-an-incomplete-terminology-guide/. For some of the likenesses between this 'automation discourse' and the recurring, contradictory capitalist fantasies of perpetual motion machines and 'circular economies', see Larry Lohmann, 'Blockchain Machines, Earth Beings and the Labour of Trust', Sturminster Newton: The Corner House, 2019, http://www.thecornerhouse.org.uk/resource/blockchain-machines-earth-beings-and-labour-trust.

[4] This strategy has a long history, stretching from C. S. Peirce's use of the term *logical machine* in the 19th century to the computer scientist Mihai Nadin's insistence on *semiotic machine* in the 21st. See Peirce, 'Logical Machines', *American Journal of Psychology* 1(1), 1887, pp. 165-170; Nadin, 'Semiotic Machine', *The Public Journal of Semiotics* 1(1), 2007, pp. 57-75 and Winfried Nöth, 'Semiotic Machines', *Cybernetics and Human Knowing*, 9(1), 2002, pp. 5-21. See also Christian Madsbjerg, *Sensemaking: The Power of the Humanities in the Age of the Algorithm*, New York: Hachette, 2017.

[5] Simon Schaffer, 'Babbage's Intelligence', *Critical Inquiry*, 21(1), 1994, pp. 203-227, pp. 204, 208, 223; Schaffer, 'Babbage's Dancer and the Impresarios of Mechanism', in *Cultural Babbage: Technology, Time and Invention*, London: Faber, 1996, pp. 53-80.

[6] Arthur W. Burks, ed., *The Collected Papers of Charles Sanders Peirce,* Vols. VII-VIII, Cambridge, MA: Harvard University Press, 1958, 7.362-366.

[7] Matteo Pasquinelli recalls some of the longer history of left discussions around this point in 'On the Origins of Marx's General Intellect', *Radical Philosophy* 2.06, Winter 2019, pp. 43-56. See also his 'Italian Operaismo and the Information Machine', *Theory, Culture and Society* 32 (3), 2015, pp. 49–68.

[8] Hamid R. Ekbia and Bonnie Nardi, *Heteromation, and other Stories of Computers and Capitalism*, Cambridge, MA: MIT Press, 2017, p. 140.

[9] Matteo Pasquinelli and Vladan Joler, 'The Nooscope Manifested: Artificial Intelligence as Instrument of Knowledge Extractivism', *Artificial Intelligence and Society*, forthcoming.

[10] See, for example, Naoki Sakai, 'Translation', *Theory, Culture and Society* 23 (2-3), 2006., pp. 71-78; W. v. O. Quine, *Word and Object*, Cambridge: MIT Press, 1960; Donald Davidson, 'A Nice Derangement of Epitaphs', in Ernest Lepore (ed.), *Truth and Interpretation: Perspectives on the Philosophy of Donald Davidson,* Oxford: Blackwell, 1989, pp. 433-446; Lydia He Liu, 'The Question of Meaning-Value in the Political Economy of the Sign', in Lydia H. Liu, ed., *Tokens of Exchange: The Problem of Translation in Global Circulations*, Durham:

Duke University Press, 2000, pp. 13-41; Eduardo Viveiros de Castro, 'Perspectival Anthropology and the Method of Controlled Equivocation', *Tipití* 2 (1), 2004, pp. 3–22; Boaventura de Sousa Santos, 'The Future of the World Social Forum: The Work of Translation', *Development* 48 (2), 2005, pp. 15–22.

[11] This second, specifically computational moment of reification or fetishization of meanings and beliefs was in fact pioneered in 1842 by Ada Lovelace in her editorial notes to her translation of L. F. Menabrea's *Sketch of the Analytical Engine Invented by Charles Babbage, Esq.*, reprinted in B. V. Bowden (ed.), *Faster than Thought: A Symposium on Digital Computing Machines*, London: Pitman and Sons, 1953, pp. 341-408. Lovelace, together with Babbage, was inspired by the example of the dead labour (as Marx would have called it) frozen into the punched cards of the programmable Jacquard loom brought into service against Lyon silk-weavers in the early 1800s. (See James Essinger, *Jacquard's Web: How a Hand-Loom Led to the Birth of the Information Age*, Oxford: Oxford University Press, 2004.) Lovelace's reification was then built on in the 1930s and 1940s by Alan Turing in the UK, Claude Shannon in the US and many others. See Andrew Hodges, *Alan Turing: The Enigma*, Centenary Edition, Princeton: Princeton University Press, 2012; Claude Shannon and Warren Weaver, *The Mathematical Theory of Communication*, Urbana: University of Illinois Press, 1963.

[12] Donald Davidson, *Inquiries into Truth and Interpretation*, Oxford University Press, Oxford, 2001; W. v. O. Quine, *Ontological Relativity and Other Essays*, New York: Columbia University Press, 1969; Daniel Dennett, *The Intentional Stance*, Cambridge, MA: MIT University Press, 1998; Hans-Johann Glock, 'On Safari with Wittgenstein, Quine and Davidson', in R. L. Arrington and H.-J. Glock, eds., *Wittgenstein and Quine,* London: Routledge, 1996, pp. 144-172.

[13] The classic explication of wayfinding (and its differences with navigating, mapping and map-following) is Tim Ingold, 'To Journey along a Way of Life: Maps, Wayfinding and Navigation', in Ingold, *The Perception of the Environment: Essays on Livelihood, Dwelling and Skill*, London: Routledge, 2000, 219-242. 'One can no more know *in* places than travel in them,' Ingold writes (p. 229).

[14] Walter Benjamin, 'Theses on the Philosophy of History', VI, 1940.

[15] H. M. Collins, *Artificial Experts: Social Knowledge and Intelligent Machines*, Cambridge, MA: MIT Press, 1990; Hodges, *Alan Turing*; Jean Lave, *Cognition in Practice: Mind, Mathematics and Culture in Everyday Life*, Cambridge: Cambridge University Press, 1988.

[16] Davidson, *Inquiries*; Lydia He Liu, *Clash of Empires: The Invention of China in Modern World-Making*, Cambridge, MA: Harvard University Press, 2006.

[17] Paul Grice, *Studies in the Way of Words,* Cambridge, MA: Harvard University Press, 1991.

[18] H. M. Collins, *Changing Order: Replication and Induction in Scientific Practice*, Chicago: University of Chicago Press, 1992; Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England*, Chicago: University of Chicago Press, 1994; Costas Lapavitsas, *Social Foundations of Markets, Money and Credit*, London: Routledge, 2003; Tim Ingold, 'From Trust to Domination: An Alternative History of Human–Animal Relations', in Ingold, *Perception*, pp. 61-76.

[19] Johan Huizinga, *Homo Ludens: A Study of the Play Element in Culture*, London: Routledge, 1949.

[20] Ludwig Wittgenstein, *Philosophical Investigations*, Translated by Elizabeth Anscombe, Oxford: Blackwell, 1953. See also Hannah Ginsborg, 'Wittgenstein on Going on', *Canadian Journal of Philosophy*, 50(1), 2020, pp. 1–17; Martin Kusch, *A Sceptical Guide to Meaning and Rules: Defending Kripke's Wittgenstein*, London: Routledge, 2006 and Harry M. Collins and Martin Kusch, *The Shape of Actions: What Humans and Machines Can Do*, Cambridge, MA: MIT Press, 1998.

[21] The labour skills on this particular list heavily involve the use of human language. However, they sit on a longer spectrum of related abilities that does not suddenly come to an end at species boundaries, or even organism or cellular boundaries. See, for example, Robert Rosen, *Anticipatory Systems. Philosophical, Mathematical, and Methodological Foundations*, New York: Springer, 2012; Mihai Nadin, 'Machine Intelligence: A Chimera', *Artificial Intelligence and Society,* 34, 2019, pp. 215–242; Brian Massumi, *What Animals Teach Us about Politics,* Durham: Duke University Press, 2014; Robert W. Mitchell, ed. *Pretending and Imagination in Animals and Children*, Cambridge: Cambridge University Press, 2002; and Jason Hribal, *Fear of the Animal Planet: The Hidden History of Animal Resistance,* Oakland: AK Press, 2011. Nor are abilities to 'go on' centred exclusively on language even in humans, as witness the Soviet physiologist Nikolai Bernstein's work on 'repetition without repetition', which has been applied to the understanding of sports, music, medicine and other activities; see Josef M. Feigenberg, *Nikolai Bernstein: From Reflex to the Model of the Future*, Translated by Julia Linkova, Zurich: LIT Verlag, 2014 and Mihai Nadin, ed., *Anticipation: Learning from the Past. The Russian/Soviet Contributions to the Science of Anticipation*, Cham: Springer, 2015. There's no space in this article to touch on the parallels between the contradictions that afflict the mid-20th-century use of a fetishized notion of 'information' in interpretation machines and those that arise from its use in molecular biology and genetic engineering.

[22] Arlie Hochschild, 'Love and Gold', in L. Ricciutelli, ed., *Women, Power and Justice: A Global Perspective*, London: Zed Books, 2005.

[23] Karl Marx, *Capital*, Vol. 3, Translated by D. Fernbach, London: Penguin Classics, 1991, pp. 270, 299.

[24] Caffentzis, *In Letters of Blood and Fire*, p. 45.

[25] Helmut Grabner, Juergen Gall and Luc Van Gool, 'What Makes a Chair a Chair?', *Proceedings of the Conference on Computer Vision and Pattern Recognition,* Institute of Electrical and Electronic Engineers, Providence, RI, 2011, pp. 1529-1536; Bing Liu, *Sentiment Analysis: Mining Opinions, Sentiments and Emotions,* Cambridge: Cambridge University Press, 2015; Andre Esteva, Brett Kuprel, Roberto A. Novoa et al., 'Dermatologist-Level Classification of Skin Cancer with Deep Neural Networks', *Nature* 542, 2017, pp. 115–118; Siddhartha Mukh, 'A.I. Versus M.D.: What Happens when Diagnosis is Automated?', *The New Yorker,* 3 April 2017, https://www.newyorker.com/magazine/2017/04/03/ai-versus-md; Shoshana Zuboff, *The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power*, New York: Public Affairs, 2019, p. 278.

[26] 'New Digital Supply Chains are Powered by Artificial Intelligence and Predictive Analytics', *Supply Chain 24/7*, 17 December 2018, https://247customsbroker.com/index.php/2018/12/18/new-digital-supply-chains-are-powered-byartificial-intelligence-and-predictive-analytics/.

[27] Kate Crawford and Trevor Paglen, 'Excavating AI: The Politics of Images in Machine Learning Training Sets', n.d., https://www.excavating.ai/.

[28] Joseph Weizenbaum, *Computer Power and Human Reason: From Judgement to Calculation*, New York: W. H. Freeman, 1976.

[29] Lohmann, 'Blockchain Machines'.

[30] Harry Collins, *Artifictional Intelligence*, Cambridge: Policy Press, 2018.

[31] Lohmann, 'Blockchain Machines'; Catherine Tubb and Tony Seba, *Rethinking Food and Agriculture 2020-2030: The Second Domestication of Plants and Animals, the Disruption of the Cow, and the Collapse of Industrial Livestock Farming*, RethinkX, September 2019, https://www.rethinkx.com.

[32] Leo Lewis, 'Can Robots Make up for Japan's Care Home Shortfall?', *Financial Times*, 17 October 2017.

[33] Shana Lynch, 'Andrew Ng: Why AI Is the New Electricity', Insights by Stanford Business, 11 March 2017, https://www.gsb.stanford.edu/insights/andrew-ng-why-ai-new-electricity; Kiran Bhageshpur, 'Data is the New Oil – and that's a Good Thing', Forbes Technology Council, 15 November 2019, https://www.forbes.com/sites/forbestechcouncil/2019/11/15/data-is-the-new-oil-and-thats-a-good-thing/#2cf7f1897304. See also David H. Autor, 'Why Are There Still So Many Jobs? The History and Future of Workplace Automation', *Journal of Economic Perspectives*, 29(3), 2015, pp. 3-30.

[34] See, for example, the studies carried out by the Oxford Martin School Programme on the Future of Work, https://www.oxfordmartin.ox.ac.uk/future-of-work and by McKinsey Global Institute, e.g., James Manyika, Susan Lund, Michael Chui et al., *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation*, https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages# For a brief, entertaining and informed critique of methodologies for quantifying in advance the number of various jobs at risk, see 'An A to Z of Jobs that Will Go' in Toby Walsh, *Machines that Think: The Future of Artificial Intelligence*, Amherst, New York: Prometheus, 2018.

[35] Lohmann, 'Blockchain Machines'.

[36] Batya Weinbaum and Amy Bridges, 'The Other Side of the Paycheck: Monopoly Capital and the Structure of Consumption,' *Monthly Review*, 28 (3), 1976; Ursula Huws, 'The Underpinnings of Class in the Digital Age,' *Socialist Register* 2014, pp. 80-107.

[37] Don Tapscott, "Understand Blockchain in under 7 Minutes," Lloyds Bank, *YouTube*, 22 March 2018, https://www.youtube.com/watch?v=isuAPyuqS7Y.

[38] Dan Schiller, *Digital Depression: Information Technology and Economic Crisis*, Urbana: University of Illinois Press, 2014.

[39] Pasquinelli, 'Italian Operaismo', p. 63, citing posthumously-published work by Gilbert Simondon.

[40] Andrew Ure, 'On the Thermostat or Heat Governor', *Philosophical Transactions of the Royal Society of London*, 1831.

[41] Essinger, *Jacquard's Web*, p. 38.

[42] Adam Geitgey, 'Text Classification is Your New Secret Weapon,' *Medium,* 15 August 2018, https://medium.com/@ageitgey/text-classification-is-your-new-secret-weapon-7ca4fad15788; Ajay Agrawal, Joshua Gans and Avi Goldfarb, *Prediction Machines: The Simple Economics of Artificial Intelligence*, Cambridge, MA: Harvard Business Review Press, 2018; Dave Gershgorn, 'We don't understand how AI make most decisions, so now algorithms are explaining themselves', *Quartz,* 20 December 2016, https://qz.com/865357/we-dont-understand-how-ai-make-most-decisions-so-now-algorithms-are-explaining-themselves/.

[43] Zuboff, *Surveillance Capitalism*, p. 254. See also "Introducing FBLearner Flow: Facebook's AI Backbone," Facebook Code, 16 April 2018, https://code.facebook.com/posts/1072626246134461/introducing-fblearnerflow-facebook-s-ai-backbone.

[44] Simon Schaffer, 'Babbage's Dancer'. As early as the 1830s, Babbage was scoring public relations triumphs by demonstrating a machine that seemed to be able, as in one of Wittgenstein's imaginary rule-following games, to 'go on' in unexpected ways. Turing also stressed this phenomenon in his polemics of the 1940s and early 1950s.

[45] Will Douglas Heaven, 'Our Weird Behavior during the Pandemic is Messing with AI Models', *MIT Technology Review*, 11 May 2020, https://www.technologyreview.com/2020/05/11/1001563/covid-pandemic-broken-ai-machine-learning-amazon-retail-fraud-humans-in-the-loop/. In the field of artificial intelligence, the disconnect between high-energy interpretation machine actions and low-energy Wittgensteinian 'going on' is continually being rediscovered and re-expressed in formulations that tend to differ only superficially: prediction is not observation (Zuboff, *Surveillance Capitalism*), decision is not choice (Weizenbaum, *Computer Power*), measurable, bit-string 'Shannon information' is not 'semantic information' (Daniel C. Dennett, *From Bacteria to Bach and Back: The Evolution of Minds,* London: Penguin, 2018), prediction is not anticipation (Nadin, 'Machine Intelligence'), computable games cannot satisfactorily model real-life situations (Espen Gaarder Haug and Nassim Nicholas Taleb, 'Why We Have Never Used the Black-Scholes-Merton Option Pricing Formula', 2007, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.581.884&rep=rep1&type=pdf), and so forth.

[46] For example, the CO_2 emissions resulting just from the *training* (not the use) of a single deep-learning natural language processing model can run to 284 tonnes, five times that of a car driven for a lifetime (Emma Strubell, Ananya Ganesh and Andrew McCallum, 'Energy and Policy Considerations for Deep Learning in NLP', 57th Annual Meeting of the Association for Computational Linguistics, Florence, Italy, July 2019, https://arxiv.org/abs/1906.02243). As with industrial mass production, machine translation is more efficient than human translation in high-bulk contexts. It has been estimated that it would take 100 megawatt-hours for properly-trained humans to translate 500 million German sentences into English (half a million people working full time for nearly three weeks). By contrast, it took a typical neural machine translation system trained using data produced by the European Paracrawl project (https://paracrawl.eu/) only seven megawatt-hours over three days to do so (William Waites, 'Efficiency, Energy Use and Sustainability in Machine Translation', The Language Data Network, 20 December 2019, https://blog.taus.net/efficiency-energy-use-and-sustainability-in-machine-translation). If the only objecive were to carry out a small job, however, as with conventional commodity production, it would be pointless to set up such an energy-hungry apparatus provided human translators were available.

[47] Hugues Ferrebouf et al., 'Lean ICT: Towards Digital Sobriety', report for the Shift Project, Paris, March 2019, https://theshiftproject.org/en/article/lean-ict-our-new-report/. Bitcoin's energy expenditures stem much more from cryptographic needs than do Google's or Facebook's, which are concentrated on computer processor workload and algorithm training together with the electronic surveillance of several billion data-processing volunteers.

[48] Digiconomist, 'Ethereum Energy Consumption', n.d., https://digiconomist.net/ethereum-energy-consumption.

[49] Nathan Ensmenger, 'The Environmental History of Computing', *Technology and Culture*, 59(4), 2018, pp. S7-S33; Mél Hogan, 'Data Flows and Water Woes: The Utah Data Center', *Big Data and Society*, July–December 2015, pp. 1–12; Camilo Mora, Randi Rollins, et al., "Bitcoin Emissions Alone could Push Global Warming above 2°C," *Nature Climate Change* 8, 2018, pp., 931-933; Jennifer Gabrys, *Digital Rubbish: A Natural History of Electronics*, Ann Arbor: University of Michigan Press, 2013. This is not to mention the waste of human beings and their talents described by Marx in the pages of *Capital* and now by, for example, Jack Linchuan Qiu in *Goodbye iSlave: A Manifesto for Digital Abolition,* Urbana: University of Illinois Press, 2016 and David N. Pellow and Lisa Sun-Hee Park in *The Silicon Valley of Dreams: Environmental Injustice, Immigrant Workers and the High-Tech Global* Economy, New York: New York University Press, 2002.

[50] Jason W. Moore, *Capitalism in the Web of Life: Ecology and the Accumulation of Capital,* London: Verso, 2015.

[51] Zuboff. *Surveillance Capitalism.*

[52] Charles Babbage, *On the Economy of Machinery and Manufacture*, London: Charles Knight, 1832.

[53] Quoted in Simon Schaffer, 'OK Computer', in M. Hagner, ed., *Ecce Cortex: Beitraege zur Geschichte des modernen Gehirns* Göttingen: Wallstein Verlag, 1999, pp. 254-85.

[54] Caffentzis, *In Letters of Blood and Fire*, p. 153.

[55] Schaffer, 'Babbage's Intelligence', p. 205.

[56] Slavoj Zizek, *The Sublime Object of Ideology*, London: Verso, 1989.

[57] Karl Marx, *Economic Manuscripts of 1861-63*, Part 3: Relative Surplus Value, https://marxists.catbull.com/archive/marx/works/1861/economic/ch35b.htm.

[58] Ibid.

[59] Karl Marx, *Capital* Vol. 3, Translated by D. Fernbach, London: Penguin Classics, 1991, pp. 270 ff.

[60] Larry Lohmann, 'Bioenergy, Thermodynamics and Inequalities', in M. Backhouse and F. Rodriguez, eds., *Bioeconomy and Global Inequalities: Knowledge, Land, Labor, Biomass, Energy, and Politics,* Palgrave Macmillan, forthcoming, http://www.thecornerhouse.org.uk/resource/bioenergy-thermodynamics-and-inequalities; Larry Lohmann and Nicholas Hildyard, *Energy, Work and Finance*, Sturminster Newton: The Corner House, 2014, http://www.thecornerhouse.org.uk/resource/energy-work-and-finance.

[61] Bruno Tinel, 'Why and How Do Capitalists Divide Labour? From Marglin and back again through Babbage and Marx', *Review of Political Economy*, 25 (2), 2013, pp. 254-272. The new thermodynamic energy, of course, was also enlisted to accelerate the expansion of the very extractive frontier that helped make increased worker subjection possible. See Moore, *Capitalism in the Web of Life*.

[62] Michelle Caruso-Cabrera and Ritika Shah, 'Why One Small Washington Town Has Seen so Many Bitcoin Miners Move in', CNBC, 11 January 2018, https://www.cnbc.com/2018/01/11/wenatchee-washington-and-the-bitcoin-gold-rush.html; Mark Sounokonoko, 'China's Bitcoin Super Mines about to Power up for "Skyrocketing" Cryptocurrency', *Finance Nine*, 1 July 2019, https://finance.nine.com.au/business-news/bitcoin-libra-why-crypto-mining-is-so-difficult-tech-china-news/477e5835-3e30-46a9-abe9-cecb6993b2ca.

[63] Hubert L. Dreyfus, *What Computers Can't Do*, New York: Harper and Row, 1972; John Haugeland, *Artificial Intelligence: The Very Idea*, Cambridge, MA: MIT Press, 1985, pp. 173-176.

[64] Jane Mayer, 'The Reclusive Hedge-Fund Tycoon Behind the Trump Presidency: How Robert Mercer Exploited America's Populist Insurgency', *The New Yorker*, 17 March 2017; David Silver, Thomas Hubert, Julian Schrittwieser et al., 'A General Reinforcement Learning Algorithm that Masters Chess, Shogi and Go through Self-Play', *Science*, 362(6419), 2018, pp. 1140-1144; David Silver, Julian Schrittwieser, Karen Simonyan et al., 'Mastering the Game of Go without Human Knowledge' *Nature*, 550, 2017, pp. 354–359.

[65] David Runciman, 'AI', *London Review of Books,* 40(2), 25 January 2018.

[66] David Graeber: *Debt: The First 5,000 Years*, Brooklyn: Melville House, 2011.

[67] Peirce, 'Logical Machines'; Ekbia and Nardi, *Heteromation,* p. 145; and, for a fictional account, Ted Chiang, *The Lifecycle of Software Objects*, Burton, MI: Subterranean Press, 2010. From an orthodox economics perspective, Autor, 'Why Are There Still So Many Jobs?', p. 26, notes that while 'some of the *tasks* in many current middle-skill jobs are susceptible to automation, many middle-skill *jobs* will continue to demand a mixture of tasks from across the skill spectrum'. For historic interventions from the computer science side, see Hans Moravec, *Mind Children: The Future of Robot and Human Intelligence*, Cambridge, MA: Harvard University Press, 1988 and Rodney Brooks, 'Elephants Don't Play Chess', *Robotics and Autonomous Systems* 6, 1990, pp. 3-15. Cf. Nils J. Nilsson, 'Human-Level Artificial Intelligence? Be Serious!', *AI Magazine*, 26(4), 2005, pp. 68-75.

[68] Ekbia and Nardi, *Heteromation*.

[69] Mary L. Gray and Siddharth Suri, *Ghost Work: How to Stop Silicon Valley from Building a New Global Underclass*, New York: Houghton Mifflin Harcourt, 2019.

[70] Collins, *Artifictional Intelligence*.

[71] Ibid. See also Anja Bechmann and Geoffrey C. Bowker, 'Unsupervised by Any Other Name: Hidden Layers of Knowledge Production in Artificial Intelligence on Social Media', *Big Data and Society*, January–June 2019: 1-11.

[72] Axios, 'Artificial Intelligence Pioneer Says We Need to Start Over', *Communications of the Association for Computing Machinery*, 18 September 2018, https://cacm.acm.org/news/221108-artificial-intelligence-pioneer-says-we-need-to-start-over/fulltext. Backpropagation, one key ingredient in current efforts to mechanize interpretation, simply 'does not capture the way the brain works', writes computer scientist Sridhar Mahadevan, one of Hinton's followers. See 'Why is Geoffrey Hinton Suspicious of Backpropagation and Wants AI to Start Over?', *Quora*, 21 September 2017, https://www.quora.com/Why-is-Geoffrey-Hinton-suspicious-of-backpropagation-and-wants-AI-to-start-over.

[73] Graeber, *Debt*; Madsbjerg, *Sensemaking.*

[74] Nancy Fraser, 'Behind Marx's Hidden Abode,' *New Left Review* 86, 2014, pp. 55-72; Moore, *Capitalism in the Web of Life.*

[75] Frank Levy and Richard Murnane, *The New Division of Labor: How Computers Are Creating the Next Job Market,* Princeton: Princeton University Press, 2004.

[76] Gray and Suri, *Ghost Work*, pp. 38–63.

[77] Marx, *Economic Manuscripts of 1861-63.*

[78] Gray and Suri, *Ghost Work*, p. 43.

[79] Ibid., pp. xxiii, 170.

[80] 'Clearview AI', Wikipedia, n.d., https://en.wikipedia.org/wiki/Clearview_AI; Clearview, 'Computer Vision for a Safer World', n.d., https://clearview.ai/; Kashmir Hill, 'The Secretive Company That Might End Privacy as We

Know It', *New York Times*, 18 January 2020.

[81] Lohmann, 'Blockchain Machines'.

[82] Ekbia and Nardi, *Heteromation*, pp. 131-140, 145. For an illuminating fictional account by a computer scientist of why the expense of hiring years of living human labour to train such 'companion machines' would discourage capitalist investment in them, see also Chiang, *Lifecycle*. 'Experience', concludes one of Chiang's characters, 'is algorithmically incompressible'.

[83] The significance of machines that can tap this seemingly trivial form of work in bulk is exemplified in the finding of researchers at Microsoft's Bing search engine that 'even a 0.1 per cent accuracy improvement in our production [of predictions] would yield hundreds of millions of dollars in additional earnings' in delivering the most effective targeted ads to users (quoted in Zuboff, *The Age of Surveillance Capitalism*, p. 85). By 2015, 90 per cent of US smartphone owners used apps that required location data feeds (p. 221).

[84] Scott Galloway, *The Four: The Hidden DNA of Amazon, Apple, Facebook and Google,* New York: Penguin, 2017, p. 6.

[85] Huber, 'Energizing Historical Materialism', p. 110.

[86] Doug Laney, 'To Facebook, You're Worth $80.95', *Wall Street Journal*, 3 May 2012, http://blogs.wsj.com/cio/2012/05/03/to-facebook-youre-worth-80-95.

[87] Ekbia and Nardi, *Heteromation*, pp. 139-140.

[88] Marx, *Capital,* Vol. 3, p. 524.

[89] Collins and Kusch, *The Shape of Actions*; Hamid R. Ekbia, 'Heteronomous Humans and Autonomous Agents: Toward Artificial Relational Intelligence', in J. Fodor and I. Ruda, eds., *Beyond Artificial Intelligence: The Disappearing Human-Machine Divide. Topics in Intelligent Engineering and Infomatics*, vol. 9, Heidelberg: Springer, pp. 63-78.

[90] Collins, *Artificial Experts.*

[91] Nathan Ensmenger, presentation for Leverhulme Centre for the Future of Intelligence, 'The Future of Artificial Intelligence: Views from History', panel discussion at Cambridge University, 29 November 2018, https://www.youtube.com/watch?v=hjB35dRUhi4.

[92] Ekbia and Nardi, *Heteromation*, pp. 140-145.

[93] William Thompson, *An Inquiry Into the Principles of the Distribution* of *Wealth Most Conducive to Humane Happiness Applied to the Newly Proposed System of Voluntary Equality of Wealth*, London: Longman, 1824, quoted in Pasquinelli, 'On the Origins', p. 50.

[94] Jason W. Moore, ' Endless Accumulation, Endless (Unpaid) Work?', *Occupied Times,* 29 April 2015.

[95] Caffentzis, *In Letters of Blood and Fire*, p. 46.

[96] Ibid. Tensor processing units are an example of a hardware advance motivated by the needs of neural network machine learning. Other processor advances have been spurred by blockchain's trust-mechanization requirements.

[97] Zuboff, *Surveillance Capitalism.* See also Agrawal, Gans and Avi Goldfarb, *Prediction Machines*.

[98] James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*, New Haven: Yale University Press, 1999.

[99] Lauren Henry Scholz, "Algorithmic Contracts," *Stanford Technology Law Review* 20, 2017, pp. 128-69, p. 132.

[100] Jerry Z. Muller, *The Tyranny of Metrics*, Princeton: Princeton University Press, 2018. See also Kartik Hosanagar, *A Human's Guide to Machine Intelligence: How Algorithms are Shaping Our Lives and How We Can Stay in Control*, New York: Viking, 2019; Hosanagar, Daniel M. Fleder, Dokyun Lee et al. 'Will the Global Village Fracture into Tribes: Recommender Systems and Their Effects on Consumers', *Management Science*, 60(4), 2014, pp. 805-823; Carole Cadwalladr, 'Google, Democracy and the Truth about Internet Search', *The Guardian,* 4 December 2016, https://www.theguardian.com/technology/2016/dec/04/google-democracy-truth-internet-search-facebook; Eytan Bakshy, Solomon Messing and Lada A. Adamic, 'Exposure to Ideologically Diverse News and Opinion on Facebook', *Science* 348(6239), 2015, pp. 1130-1132.