Matteo Pasquinelli

The Automation of General Intelligence

> We want to ask the right questions. How do the tools work? Who finances and builds them, and how are they used? Whom do they enrich, and whom do they impoverish? What futures do they make feasible, and which ones do they foreclose? We're not looking for answers. We're looking for logic.
> —*Logic Magazine* manifesto, 2017[1]

> We live in the age of digital data, and in that age mathematics has become the parliament of politics. The social law has become interwoven with models, theorems and algorithms. With digital data, mathematics has become the dominant means in which human beings coordinate with technology … Mathematics is a human activity after all. Like any other human activity, it carries the possibilities of both emancipation and oppression.
> —Politically Mathematics manifesto, 2019[2]

> Relics of bygone instruments of labour possess the same importance for the investigation of extinct economic formations of society as do fossil bones for the determination of extinct species of animals. It is not what is made but how, and by what instruments of labour, that distinguishes different economic epochs. Instruments of labour not only supply a standard of the degree of development which human labour has attained, but they also indicate the social relations within which men work.
> —Karl Marx, *Capital*, 1867[3]

There will be a day in the future when current AI will be considered an archaism, one technical fossil to study among others.[4] In the passage from *Capital* quoted above, Marx suggested a similar analogy that resonates with today's science and technology studies: in the same way in which fossil bones disclose the nature of ancient species and the ecosystems in which they lived, similarly, technical artifacts reveal the form of the society that surrounds and runs them. The analogy is relevant, I think, for all machines and also for machine learning, whose abstract models do in reality encode a concretion of social relations and collective behaviors, as this book has tried to demonstrate in reformulating the nineteenth-century labor theory of automation for the age of AI.

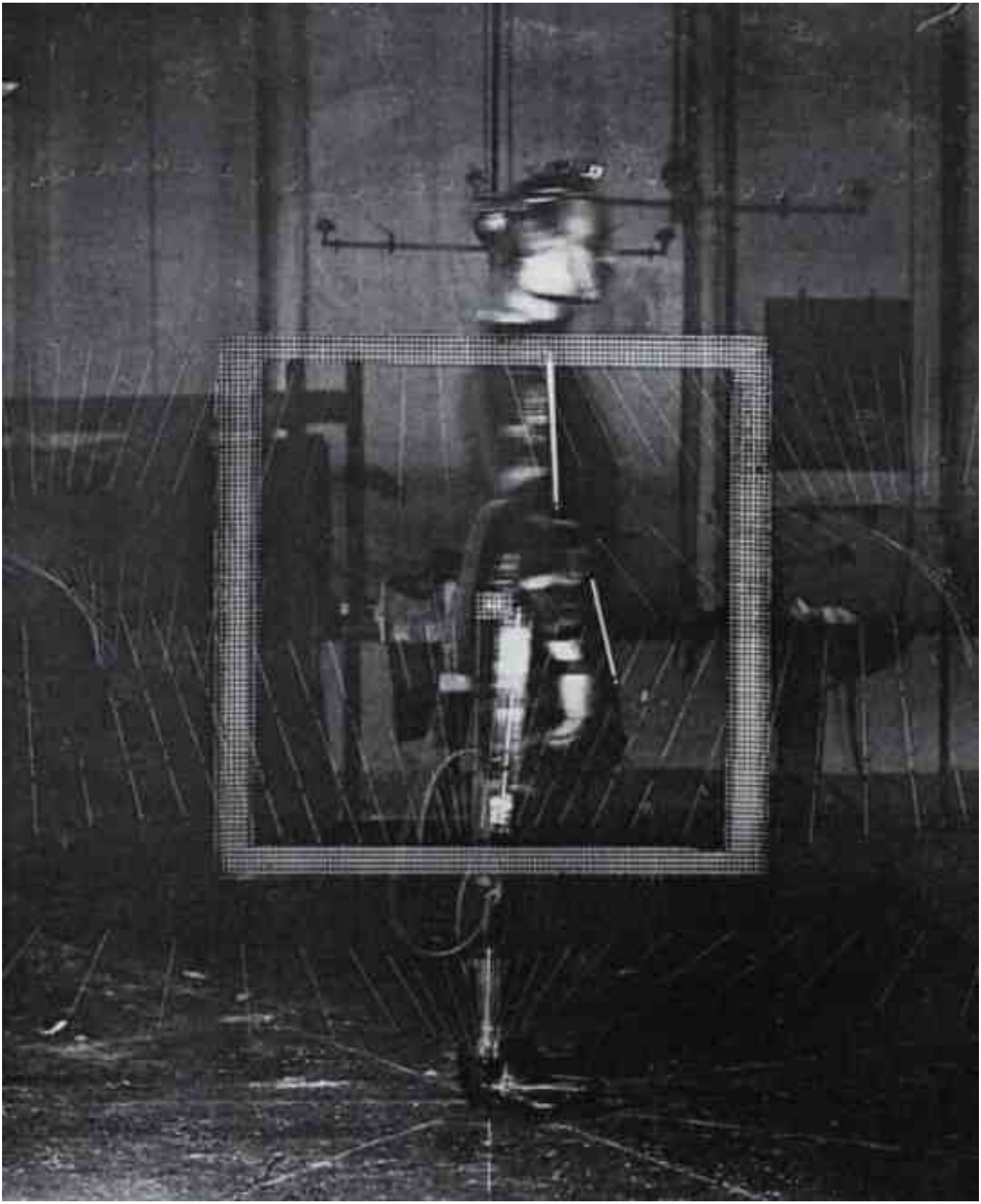
This book [*The Eye of the Master*] began with a simple question: What relation exists between labor, rules, and automation, i.e., the invention of new technologies? To answer this question, it has illuminated practices, machines, and algorithms from different perspectives—from the "concrete" dimension of production and the "abstract" dimension of disciplines such as mathematics and computer science. The concern, however, has not been to repeat the separation of the concrete and abstract domains but to see their

An illustration of Henry Case and Molly Minions from Neuromancer, painting by Juan Giménez.

coevolution throughout history: eventually to investigate labor, rules, and automation, dialectically, as *material abstractions.* The initial chapter emphasized this aspect by highlighting how ancient rituals, counting tools, and "social algorithms" all contributed to the making of mathematical ideas. To affirm, as did the introduction, that *labor is a logical activity* is not a way of abdicating to the mentality of industrial machines and corporate algorithms, but rather of recognizing that human praxis expresses its own logic (an *anti-logic*, some might say)—a power of speculation and invention, before techno-science captures and alienates it.[5]

The thesis that labor has to become "mechanical" on its own, before machinery replaces it, is an old fundamental principle that has simply been forgotten. It dates back at least to Adam Smith's exposition in *The Wealth of Nations* (1776), which Hegel also commented upon already in his Jena lectures (1805–6). Hegel's notion of "abstract labor," as labor that gives "form" to machinery, was already indebted to British political economy before Marx contributed his own radical critique of the concept. It fell to Charles Babbage to systematize Adam Smith's insight in a consistent "labor theory of automation." Babbage complemented this theory with the "principle of labor calculation" (known since then as the "Babbage principle") to indicate that the division of labor also allows the precise computation of labor costs. This book can be considered an exegesis of Babbage's two "principles of labor analysis" and their influence on the common history of political economy, automated computation, and machine intelligence. Although it may sound anachronistic, Marx's theory of automation and relative surplus-value extraction share common postulates with the first projects of machine intelligence.

Marx overturned the industrialist perspective—"the eye of the master"—that was inherent in Babbage's principles. In *Capital*, he argued that the "social relations of production" (the division of labor within the wage system) drive the development of the "means of production" (tooling machines, steam engines, etc.) and not the other way around, as techno-deterministic readings have been claiming then and now by centering the industrial



In the 1890s, the German anatomist Christian Wilhelm Braune and Otto Fischer published a series of papers on the biomechanics of human gait under loaded and unloaded conditions.

revolution around technological innovation only. Of these principles of labor analysis Marx also made something else: he considered the cooperation of labor not only as a principle to explain the design of machines but also to define the political centrality of what he called the "*Gesamtarbeiter*," the "general worker." The figure of the general worker was a way of acknowledging the machinic dimension of living labor and confronting the "vast automaton" of the industrial factory on the same scale of complexity. Eventually, it was also a necessary figure to ground, on a more solid politics, the ambivalent idea of the "general intellect" that Ricardian socialists such as William Thompson and Thomas Hodgskin pursued.

F rom the Assembly Lines to Pattern Recognition

This book has provided an expanding history of the division of labor and its metrics as a way to identify the operative principle of AI in the long run. As we have seen, at the turn of the nineteenth century, the more the division of labor extended into a globalized world, the more troublesome its management became, requiring new techniques of communication, control, and "intelligence." While, within the manufactory, labor management could be still sketched in a simple flow chart and measured by a clock, it was highly complicated to visualize and quantify what Emile Durkheim, already in 1893, defined as "the division of social labor."[6] The "intelligence" of the factory's master could no longer survey the entire production process in a single glance; now, only the infrastructures of communication could achieve this role of supervision and quantification. New mass media, such as the telegraph, telephone, radio, and television networks, made possible communication across countries and continents, but they also opened up new perspectives on society and collective behaviors. James Beniger aptly described the rise of information technologies as a "control revolution" that proved necessary in that period for governing the economic boom and commercial surplus of the Global North. After World War II, the control of this extended logistics became the concern of a new discipline of the military that bridged mathematics and management: operations research. However, it should be considered that the transformations of the working class within and across countries, marked by cycles of urban conflicts and decolonial struggles, were also among the factors that prompted the rise of these new technologies of control.

The scale shift of labor composition from the nineteenth to the twentieth centuries also affected the *logic of automation*, that is, the scientific paradigms involved in this transformation. The relatively simple industrial division of labor and its seemingly rectilinear assembly lines could easily be compared to a simple *algorithm*, a rule-based procedure with an "if/then" structure which has its equivalent in the logical form of *deduction*. Deduction, not by coincidence, is the logical form that via Leibniz, Babbage, Shannon, and Turing innervated into electromechanical computation and eventually symbolic AI. Deductive logic is useful for modelling simple processes, but not systems with a multitude of autonomous agents, such as society, the market, or the brain. In these cases, deductive logic is inadequate because it would explode any procedure, machine, or algorithm into an exponential number of instructions. Out of similar concerns, cybernetics started to investigate self-organization in living beings and machines to simulate order into high-complexity systems that could not be easily organized according to hierarchical and centralized methods. This was fundamentally the rationale behind connectionism and artificial neural networks and also early research on distributed networks of communication such as Arpanet (the progenitor of the internet).

Across the twentieth century, many other disciplines recorded the growing complexity of social relations. The twin concepts of "Gestalt" and "pattern," for instance, as employed respectively by Kurt Lewin and Friedrich Hayek, were an example of how psychology and economics responded to a new composition of society. Lewin introduced holistic notions such as "force field" and "hodological space" to map group dynamics at different scales between the individual and mass society.[7]

French thought has been particularly fertile and progressive in this direction. The philosophers Gaston Bachelard and Henri Lefebvre proposed, for example, the method of "rhythmanalysis," as a study of social rhythms in the urban space (which Lefebvre described according to the four typologies of arrhythmia, polyrhythmia, eurhythmia, and isorhythmia).[8] In a similar way, French archaeology engaged with the study of expanded forms of social behavior in ancient civilizations. For instance, the paleoanthropologist André Leroi-Gourhan, together with others, introduced the idea of the operational chain (*chaîne opératoire*) to explain the way prehistoric humans produced utensils.[9] At the culmination of this long tradition of the "diagrammatization" of social behaviors in French thought, Gilles Deleuze wrote his famous "Postscript on the Society of Control," which declared that power was no longer concerned with the discipline of individuals but with the control of "dividuals," that is of the fragments of an extended and deconstructed body.[10]

Lewin's force fields, Lefebvre's urban rhythms, and Deleuze's dividuals can be seen as predictions of the principles of "algorithmic governance" which have been established with the network society and its vast data centers since the late 1990s. The 1998 launch of Google's PageRank algorithm—a method for organizing and searching the chaotic hypertext of the web—is considered, by convention, the first large-scale elaboration of "big data" from digital networks.[11] These techniques for network mapping have become ubiquitous nowadays: Facebook, for instance, uses the Open Graph protocol to quantify the networks of human relations that feed the attention economy of its platform.[12] The US military has been using its own controversial techniques of "pattern-of-life analysis" to map social networks in war zones and to identify targets of drone strikes which, as is

The Magnanimous Cuckold, directed by Vsevolod Meyerhold, 1922.

well known, have killed innocent civilians.[13] More recently, gig economy platforms and logistics giants such as Uber, Deliveroo, Wolt, and Amazon have started to trace their fleet of riders and drivers via geolocation apps.[14] All these techniques are part of the new field of "people analytics" (also known as "social physics" or "psychographics"), which is but the application of statistics, data analytics, and machine learning to the problem of labor power in postindustrial society.[15]

T he Automation of Psychometrics, or General Intelligence

The division of labor, as much as the design of machines and algorithms, is not an abstract form per se but a means for measuring labor and social behaviors and differentiating people according to their productive capacity. As the Babbage principles indicate, any division of labor entails a metrics: a measurement of workers' performativity and efficiency, but also a judgement about classes of skill, which involves an implicit social hierarchy. Metrics of labor were introduced to assess what is and is not productive, to manipulate a social asymmetry while declaring an equivalence to the money system. During the modern age, factories, barracks, and hospitals have pursued a discipline and organization of bodies and minds with similar methods, as Michel Foucault sensed, among others.

At the end of the nineteenth century, the metrology of labor and behaviors found an ally in a new field of statistics: psychometrics. Psychometrics had the purpose of measuring the skills of the population in resolving basic tasks, making statistical comparisons on cognitive tests rather than taking measurements of physical performance as in the earlier field of psychophysics.[16] As part of the controversial legacy of Alfred Binet, Charles Spearman, and Louis Thurstone, psychometrics can be considered one of the main genealogies of statistics, which has never been a neutral discipline so much as one concerned with the "measure of man," the institution of norms of behavior, and the repression of abnormalities.[17] The transformation of the metrics of labor into the *psychometrics of labor* is a key passage for both management and technological development in the twentieth century. It is telling that in designing the first artificial neural network perceptron, Frank Rosenblatt was not only inspired by theories of neuroplasticity but also by tools of multivariable analysis that psychometrics imported into US psychology in the 1950s.

From this perspective, this book has attempted to clarify how the project of AI has actually emerged from the automation of the psychometrics of labor and social behaviors rather than from the quest to solve the "enigma" of intelligence. In a concise summary of the history of AI, one could say that the mechanization of the "general intellect" of the industrial age into the "artificial intelligence" of the twenty-first century was made possible thanks to the statistical measurement of skill, such as Spearman's "general intelligence" factor and its subsequent automation into artificial neural networks. If in the industrial age the machine was considered an embodiment of science, knowledge, and the "general intellect" of workers, in the information age artificial neural networks have become the first machines to encode "general intelligence" into statistical tools—at the beginning, specifically, to automate pattern recognition as one of the key tasks of "artificial intelligence." In short, the current form of AI, machine learning, is the automation of the statistical metrics that were originally introduced to quantify cognitive, social, and work-related abilities. The application of psychometrics through information technologies is not a phenomenon unique to machine learning. The 2018 Facebook–Cambridge Analytica data scandal, in which the consulting firm was enabled to collect the personal data of millions without their consent, is a reminder of how large-scale psychometrics is still used by corporate and state actors in an attempt to predict and manipulate collective behaviors.[18]

Given their legacy in the statistical tools of nineteenth-century biometrics, it is also not surprising that deep artificial neural networks have recently unfolded into advanced techniques of surveillance, such as facial recognition and pattern-of-life analysis. Critical AI scholars such as Ruha Benjamin and Wendy Chun, among others, have exposed the racist origins of these techniques of identification and profiling that, like psychometrics, almost represent technical proof of the social bias of AI.[19] They have rightly identified the power of discrimination at the core of machine learning, and how this aligns it with the apparatuses of normativity of the modern age, including the questionable taxonomies of medicine, psychiatry, and criminal law.[20]

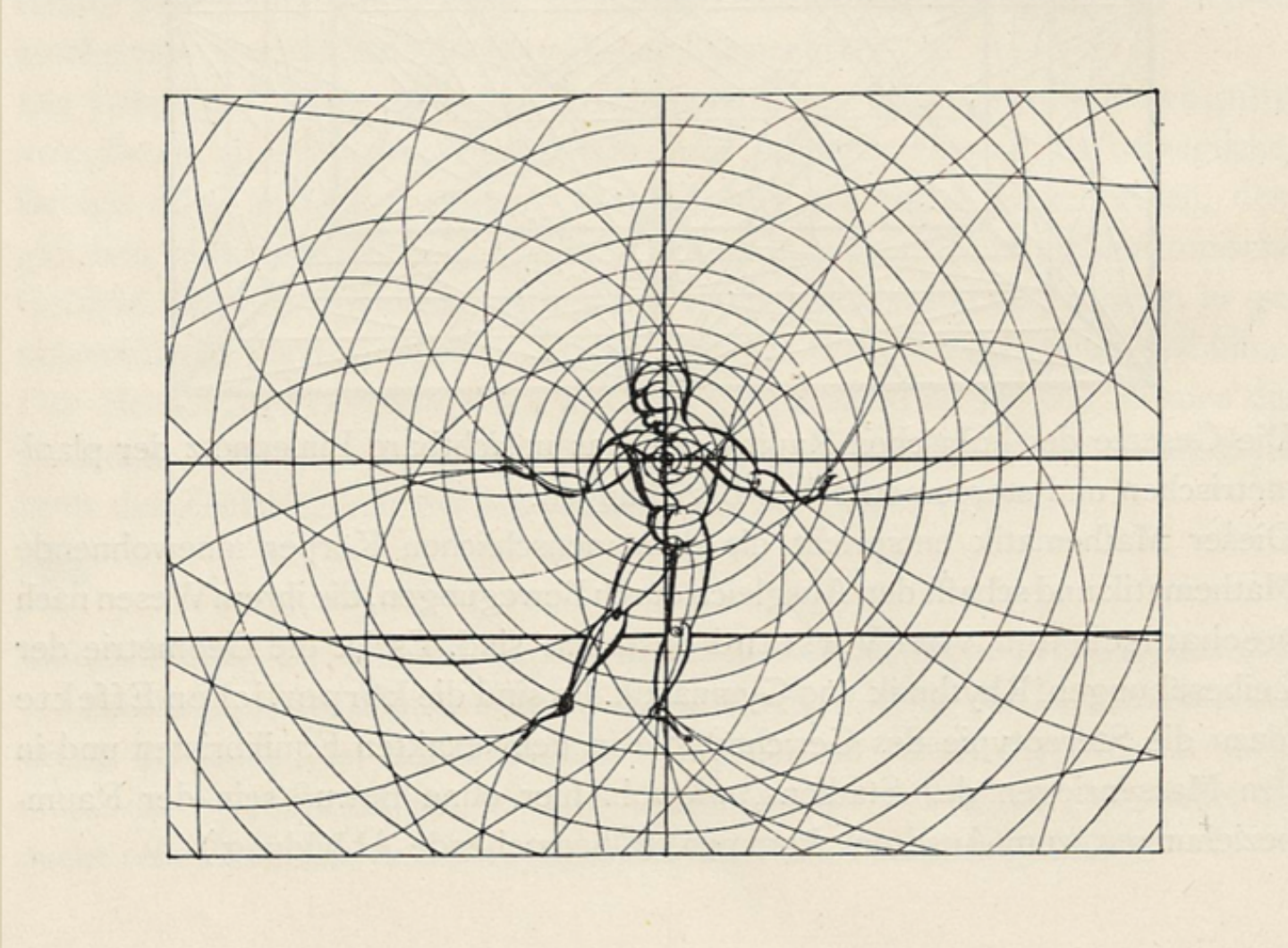
The metrology of intelligence pioneered in the late nineteenth century, with its implicit and explicit agenda of social and racial segregation, still operates at the core of AI to discipline labor and replicate productive hierarchies of knowledge. The rationale of AI is therefore not only the automation of labor but the reinforcement of these social hierarchies in an indirect way. By implicitly declaring what can be automated and what cannot, AI has imposed a new metrics of intelligence at each stage of its development. But to compare human and machine intelligence implies also a judgement about which human behavior or social group is more intelligent than another, which workers can be replaced and which cannot. Ultimately, AI is not only a tool for automating labor but also for imposing standards of *mechanical intelligence* that propagate, more or less invisibly, social hierarchies of knowledge and skill. As with any previous form of automation, AI does not simply replace workers but displaces and restructures them into a new social order.

The Automation of Automation

Looking carefully at how statistical tools that were conceived to rate cognitive skills and discriminate between people's productivity turned into algorithms, a more profound aspect of automation becomes apparent. In fact, the study of the metrology of labor and behaviors reveals that automation emerges in some cases from the transformation of the measurement instruments themselves into kinetic technologies. Tools for labor quantification and social discrimination have become "robots" in their own right. Before psychometrics, one could refer to how the clock used to measure labor time in the factory was later implemented by Babbage for the automation of mental labor in the Difference Engine. Cyberneticians such as Norbert Wiener still considered the clock as a key model for both the brain and the computer. In this respect, the historian of science Henning Schmidgen has noted how the chronometry of nervous stimuli contributed to the consolidation of brain metrology and also McCulloch and Pitts's model of neural networks.[21] The theory of automation which this book has illustrated, then, does not point only to the emergence of machines from the logic of labor management but also from the instruments and metrics for quantifying human life in general and making it productive.

This book has sought to show that AI is the culmination of the long evolution of labor automation and the quantification of society. The statistical models of machine learning do not appear, in fact, to be radically different from the design of industrial machines but rather homologous to them: they are indeed constituted by the same analytical intelligence of tasks and collective behaviors, albeit with a higher degree of complexity (i.e., number of parameters). Like industrial machines whose design gradually emerged through routine tasks and trial-and-error adjustments, machine-learning algorithms adapt their internal model to the patterns in the training data through a comparable trial-and-error process. The *design* of a machine as well as the *model* of a statistical algorithm can be said to follow a similar logic: both are based on the imitation of an external configuration of space, time, relations, and operations. In the history of AI, this was as true of Rosenblatt's perceptron (which aimed to record the gaze's movements and spatial relations of the visual field) as of any other machine-learning algorithm nowadays (e.g., support vector machines, Bayesian networks, transformer models).

Whereas the industrial machine embodies the diagram of the division of labor in a determined way (think of the components and limited "degrees of freedom" of a textile loom, a lathe, or a mining excavator), machine-learning



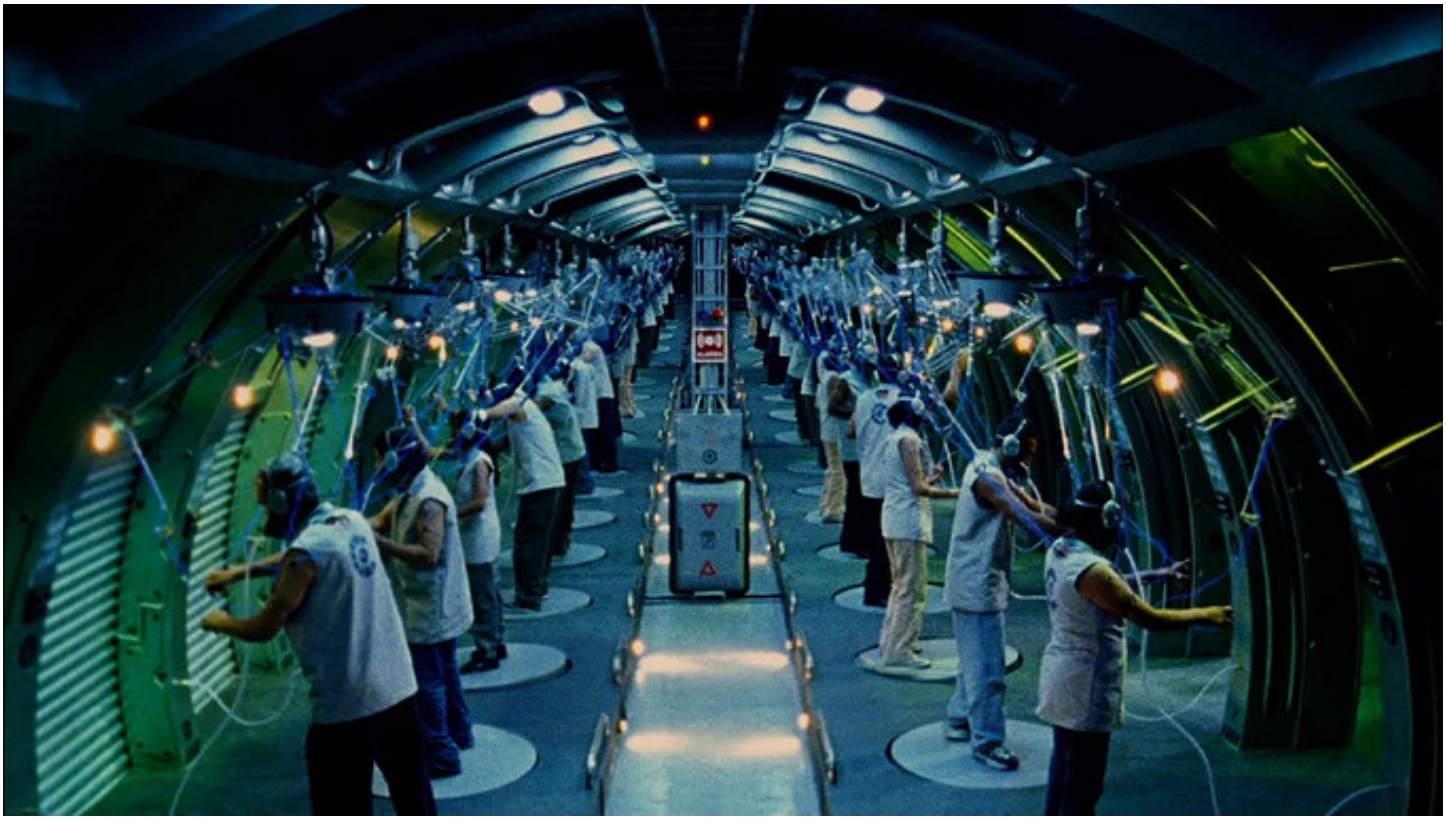
Oskar Schlemmer from Notebook n.4 of the Bauhausbucher, 1925.

algorithms (especially recent AI models with a vast numbers of parameters) can imitate complex human activities.[22] Although with problematic levels of approximation and bias, a machine-learning model is an adaptive artifact that can encode and reproduce the most diverse configurations of tasks. For example, one and the same machine-learning model can emulate the movement of robotic arms in assembly lines as much as the driver's operations in a self-driving car; the same model can also translate between languages as much as describe images with colloquial words.

The rise of large foundation models in recent years (e.g., BERT, GPT, CLIP, Codex) demonstrates how one single deep-learning algorithm can be trained on one vast integrated dataset (comprising text, images, speech, structured data, and 3D signals) and used to automate a wide range of so-called downstream tasks (question answering, sentiment analysis, information extraction, text generation, image captioning, image generation, style transfer, object recognition, instruction following, etc.).[23]

For the way in which they have been built on large repositories of cultural heritage, collective knowledge, and social data, large foundation models are the closest approximation of the mechanization of the "general intellect" that was envisioned in the industrial age. An important aspect of machine learning that foundation models demonstrate is that the automation of individual tasks, the codification of cultural heritage, and the analysis of social behaviors have no technical distinction: they can be performed by one and the same process of statistical modelling.

In conclusion, machine learning can be seen as the project to automate the very process of machine design and model making—which is to say, the automation of the labor theory of automation itself. In this sense, machine learning and, specifically, large foundation models represent a new definition of the Universal Machine, for their capacity is not just to perform computational tasks but to imitate labor and collective behaviors at large. The breakthrough that machine learning has come to



Still from Sleep Dealer, directed by Alex Rivera, 2008.

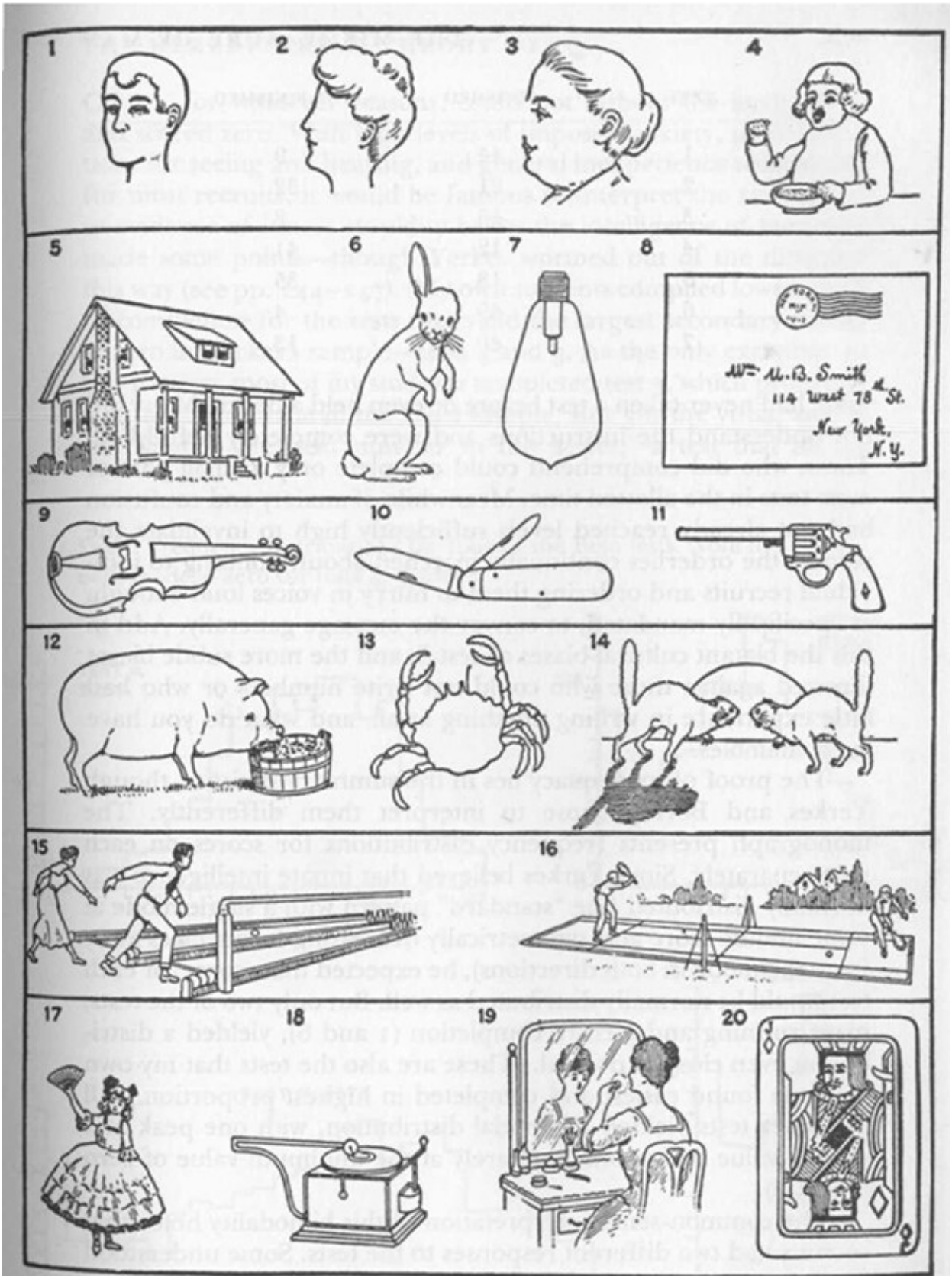
represent is therefore not just the "automation of statistics," as machine learning is sometimes described, but the *automation of automation*, bringing this process to the scale of collective knowledge and cultural heritage.[24] Further, machine learning can be considered as the technical proof of the gradual integration of labor automation and social governance. Emerging out of the imitation of the division of labor and psychometrics, machine-learning models have gradually evolved towards an integrated paradigm of governance that corporate data analytics and its vast data centers well exemplify.

Undoing the Master Algorithm

Given the growing size of datasets, the training costs of large models, and the monopoly of the cloud infrastructure that is necessary for a few companies such as Amazon, Google, and Microsoft (and their Asian counterparts Alibaba and Tencent) to host such models, it has become evident to everyone that the sovereignty of AI remains a tough affair of geopolitical scale. Moreover, the confluence of different apparatuses of governance (climate science, global logistics, and even health care) towards the same hardware (cloud computing) and software (machine learning) signals an even stronger trend toward monopolization. Aside from the notorious issue of power accumulation, the rise of data monopolies points to a phenomenon of technical convergence that is key to this book: the means of labor have become the same means of its measurement, and likewise, the means of management and logistics have become the same means of economic planning.

This became evident also during the Covid-19 pandemic, when a large infrastructure for tracking, measuring, and forecasting social behaviors was established.[25] This infrastructure, unprecedented in the history of health care and biopolitics, was not, however, created ex nihilo but built upon existing digital platforms that orchestrate most of our social relations. Particularly during the lockdowns, the same digital medium was used for working, shopping, communicating with family and friends, and eventually health care. Digital metrics of the social body such as geolocation and other metadata were key for the predictive models of the global contagion, but they have long been in use for tracking labor, logistics, commerce, and education. Philosophers such as Giorgio Agamben have claimed that this infrastructure extended the state of emergency of the pandemic, while in fact its deployment to health care and biopolitics continues decades of monitoring the economic productivity of the social body, which has passed unnoticed to many.[26]

The technical convergence of data infrastructures also reveals that contemporary automation is not just about the automation of the individual worker, as in the stereotypical image of the humanoid robot, but about the automation of the factory's masters and managers, as happens in gig



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From the book The Mismeasure of Man by Stephen Jay Gould, 1981.

economy platforms. From the giants of logistics (Amazon, Alibaba, DHL, UPS, etc.) and mobility (Uber, Share Now, Foodora, Deliveroo) to social media (Facebook, TikTok, Twitter), platform capitalism is a form of automation that in reality does not replace workers but multiplies and governs them anew. It is not so much about the automation of labor this time as it is about the automation of management. Under this new form of *algorithmic management*, we are all rendered as *dividual workers* of a vast automaton comprised of global users, "turkers," carers, drivers, and riders of many sorts. The debate on the fear that AI will fully replace jobs is misguided: in the so-called platform economy, algorithms replace management and multiply precarious jobs. Although the revenues of the gig economy remain small in relation to traditional local sectors, by using the same infrastructure worldwide these platforms have established monopoly positions. The power of the new "master" is not about the automation of individual tasks but the management of the social division of labor. Against Alan Turing's prediction, it is the master, not the worker, whom the robot has come to replace first.[27]

One wonders what the chance of political intervention in such technologically integrated space would be, and whether the call to "redesign AI" that grassroots and institutional initiatives advocate for is either reasonable or practicable. This call should first respond to a more pressing question: How is it possible to "redesign" large-scale monopolies of data and knowledge?[28] As big companies such as Amazon, Walmart, and Google have conquered unique access to the needs and problems of the whole social body, a growing movement is asking not just to make these infrastructures more transparent and accountable but actually to collectivize them as public services (as Fredric Jameson has suggested, among others), or have them replaced by public alternatives (as Nick Srnicek has advocated).[29] But what would be a different way to design such alternatives?

As this book's theory of automation has suggested, any technological and institutional apparatus, including AI, is a crystallization of a productive social process. Problems arise because such crystallization "ossifies" and reiterates past structures, hierarchies, and inequalities. To criticize and deconstruct complex artifacts such as AI monopolies, first we should engage in the meticulous work of *deconnectionism*, undoing—step by step, file by file, dataset by dataset, piece of metadata by piece of metadata, correlation by correlation, pattern by pattern—the social and economic fabric that constitutes them in origin. This work is already being advanced by a new generation of scholars who are dissecting the global production pipeline of AI, especially those who use methods of "action research." Notable, among many others, are Lilly Irani's Turkopticon platform, used for "interrupting worker invisibility" in the gig platform Amazon Mechanical Turk; Adam Harvey's investigation of training datasets for face recognition, which exposed the massive privacy infringements of AI corporations and academic research; and the work of the Politically Mathematics collective from India, which analyzed the economic impact of Covid-19 predictive models on the poorest populations and reclaimed mathematics as a space of political struggle (see their manifesto quoted at the beginning of this text).[30]

The labor theory of automation is an analytical principle for studying the new "eye of the master" that AI monopolies incarnate. However, precisely because of its emphasis on the labor process and social relations that constitute technical systems, it is also a synthetic and "sociogenic" principle (to use Frantz Fanon and Sylvia Wynter's programmatic term).[31] What is at the core of the labor theory of automation is, ultimately, a *practice of social autonomy.* Technologies can be judged, contested, reappropriated, and reinvented only by moving into the matrix of the social relations that originally constituted them. Alternative technologies should be *situated* in these social relations, in a way not dissimilar to what cooperative movements have done in past centuries. But building alternative algorithms does not mean making them more ethical. For instance, the proposal to hard-code ethical rules into AI and robots appears highly insufficient and incomplete because it does not directly address the broad political function of automation at their core.[32]

What is needed is neither techno-solutionism nor techno-pauperism, but instead a *culture of invention, design, and planning* that cares for communities and the collective, and never entirely relinquishes agency and intelligence to automation. The first step of techno-politics is not technological but political. It is about emancipating and decolonizing, when not abolishing as a whole, the organization of labor and social relations on which complex technical systems, industrial robots, and social algorithms are based—specifically their inbuilt wage system, property rights, and identity politics. New technologies for labor and society can only be based on this political transformation. It is clear that this process unfolds by developing not only technical but also political knowledge. One of the problematic effects of AI on society is its epistemic influence—the way it renders intelligence as machine intelligence and implicitly fosters knowledge as procedural knowledge. The project of a political epistemology to transcend AI, however, will have to transmute the historical forms of abstract thinking (mathematical, mechanical, algorithmic, and statistical) and integrate them as part of the toolbox of critical thinking itself. In confronting the epistemology of AI and its regime of knowledge extractivism, a different technical mentality, a collective "counter-intelligence," has to be learned.

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1
"Disruption: A Manifesto," *Logic Magazine* , no. 1 (March 2017) https://logicmag.io/intelligence/disruption-a-manifesto/ .

2
Politically Mathematics collective, "Politically Mathematics Manifesto," 2019 https://politicallymath.in/manifesto/ .

3
Karl Marx, *Capital*, vol. 1 (Penguin, 1976), 286.

4
This text is the concluding chapter of Matteo Pasquinelli, *The Eye of the Master: A Social History of Artificial Intelligence* (Verso, 2023). It has been lightly edited.—Ed.

5
See the labor process debate: Harry Braverman, *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century* (Monthly Review Press , 1974); David Noble, *Forces of Production: A Social History of Industrial Automation* (Oxford University Press, 1984).

6
Emile Durkheim, *De la division du travail social* (Félix Alcan, 1893), translated as *The Division of Labor in Society* (Free Press, 1984).

7
Kurt Lewin, "Die Sozialisierung des Taylorsystems: Eine grundsätzliche Untersuchung zur Arbeits- und Berufspsychologie," *Schriftenreihe Praktischer Sozialismus* , vol. 4 (1920). See also Simon Schaupp, "Taylorismus oder Kybernetik? Eine kurze ideengeschichte der algorithmischen arbeitssteuerung," *WSI-Mitteilungen* 73, no. 3, (2020).

8
Gaston Bachelard, *La dialectique de la durée* (Boivin & Cie, 1936), translated as *The Dialectic of Duration* (Rowman & Littlefield, 2016); Henri Lefebvre, *Éléments de rythmanalyse* (Editions Syllepse, 1992), translated as *Rhythmanalysis: Space, Time and Everyday Life* (Continuum, 2004). Bachelard took the term "rhythmanalysis" from the Portuguese philosopher Lucio Alberto Pinheiro dos Santos.

9
Frederic Sellet, "Chaıne Opératoire: The Concept and Its Applications," *Lithic Technology* 18, no. 1–2 (1993).

10
Gilles Deleuze, "Postscript on the Society of Control," *October*, no. 59 (1992). See also David Savat, "Deleuze's Objectile: From Discipline to Modulation," in *Deleuze and New Technology* , ed. Mark Poster and David Savat (Edinburgh University Press, 2009).

11
Matthew L. Jones, "Querying the Archive: Data Mining from Apriori to PageRank," in *Science in the Archives* , ed. Lorraine Daston (University of Chicago Press, 2017); Matteo Pasquinelli, "Google's PageRank Algorithm: A Diagram of Cognitive Capitalism and the Rentier of the Common Intellect," in *Deep Search*, ed. Konrad Becker and Felix Stalder (Transaction Publishers, 2009).

12
Irina Kaldrack and Theo Röhle, "Divide and Share: Taxonomies, Orders, and Masses in Facebook's Open Graph," *Computational Culture* , no. 4 (November 2014); Tiziana Terranova, "Securing the Social: Foucault and Social Networks," in *Foucault and the History of Our Present* , ed. S. Fuggle, Y. Lanci, and M. Tazzioli (Palgrave Macmillan, 2015).

13
Grégoire Chamayou, "Pattern-of-Life Analysis," chap. 5 in *A Theory of the Drone* (New Press, 2014). See also Matteo Pasquinelli, "Metadata Society," keyword entry in *Posthuman Glossary* , ed. Rosi Braidotti and Maria Hlavajova (Bloomsbury, 2018), and "Arcana Mathematica Imperii: The Evolution of Western Computational Norms," in *Former West* , ed. Maria Hlavajova and Simon Sheikh (MIT Press, 2017).

14
Andrea Brighenti and Andrea Pavoni, "On Urban Trajectology: Algorithmic Mobilities and Atmocultural Navigation," *Distinktion: Journal of Social Theory* 24, no. 1 (2001).

15
L. M. Giermindl et al., "The Dark Sides of People Analytics: Reviewing the Perils for Organisations and Employees," *European Journal of Information Systems* 33, no. 3 (2022). See also Alex Pentland, *Social Physics: How Social Networks Can Make Us Smarter* (Penguin, 2015).

16
The word "statistics" originally meant the knowledge possessed by the state about its own affairs and territories: a knowledge that had to be kept secret. Michel Foucault, *Security, Territory, Population: Lectures at the Collège de France 1977–1978* , trans. Graham Burchell (Palgrave Macmillan, 2009), 274.

17
For the influence of brain metrology on the history of AI, see Simon Schaffer: "Judgements that machines are intelligent have involved techniques for measuring brains' outputs. These techniques show how discretionary behavior is connected with the status of those who rely on intelligence for their social legitimacy." Schaffer, "OK Computer," in *Ansichten der Wissenschaftsgeschichte* , ed. Michael Hagner (Fischer, 2001). On early metrology of the nervous system, see Henning Schmidgen, *The Helmholtz Curves: Tracing Lost Times* (Fordham University Press, 2014).

18
Luke Stark, "Algorithmic Psychometrics and the Scalable Subject," *Social Studies of Science* 48, no. 2 (2018).

19
Ruha Benjamin, *Race after Technology: Abolitionist Tools for the New Jim Code* (Polity, 2019); Wendy Chun , *Discriminating Data: Correlation, Neighborhoods, and the New Politics of Recognition* (MIT Press, 2021).

20
For the imbrication of colonialism, racism, and digital technologies, see Jonathan Beller, *The World Computer: Derivative Conditions of Racial Capitalism* (Duke University Press, 2021); Seb Franklin, *The Digitally Disposed: Racial Capitalism and the Informatics of Value* (University of Minnesota Press, 2021).

21
Henning Schmidgen, "Cybernetic Times: Norbert Wiener, John Stroud, and the 'Brain Clock' Hypothesis," *History of the Human Sciences* 33, no. 1 (2020). On cybernetics and the "measurement of rationality," see Orit Halpern, *Beautiful Data: A History of Vision and Reason since 1945* (Duke University Press, 2015), 173.

22
In mechanics, the degrees of freedom (DOF) of a system such as a machine, a robot, or a vehicle is the number of independent parameters that define its configuration or state. Bicycles are usually said to have two degrees of freedom. A robotic arm can have many. A large machine-learning model such as GPT can feature more than a trillion.

23
Rishi Bommasani et al., *On the Opportunities and Risks of Foundation Models* , Center for Research on Foundation Models at the Stanford Institute for Human-Centered Artificial Intelligence, 2021 https://crfm.stanford.edu/report.html .

24
For a different reading of the automation of automation, see Pedro Domingos, *The Master Algorithm: How the Quest for the Ultimate Learning Machine Will Remake Our World* (Basic Books, 2015); Luciana Parisi, "Critical Computation: Digital Automata and General Artificial Thinking," *Theory, Culture, and Society* 36, no. 2 (March 2019).

25
"Breaking Models: Data Governance and New Metrics of Knowledge in the Time of the Pandemic," workshop, Max Planck Institute for the History of Science, Berlin, and KIM research group, University of Arts and Design, Karlsruhe, September 24, 2021 file:///Users/mandr/Downloads/kim.hfg-karlsruhe.de/breaking-models .

26
Giorgio Agamben, *Where Are We Now? The Epidemic as Politics* , trans. V. Dani (Rowman & Littlefield, 2021).

27
Min Kyung Lee et al., "Working with Machines: The Impact of Algorithmic and Data-Driven Management on Human Workers," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* , Association for Computing Machinery, New York, 2015; Sarah O'Connor, "When Your Boss Is an Algorithm," *Financial Times*, September 8, 2016. See also Alex Wood, "Algorithmic Management Consequences for Work

Organisation and Working Conditions," no. 2021/07, European Commission JRC Technical Report, Working Papers Series on Labour, Education, and Technology, 2021.

28
Redesigning AI , ed. Daron Acemoglu (MIT Press), 2021.

29
Leigh Phillips and Michal Rozworski, *The People's Republic of Walmart: How the World's Biggest Corporations Are Laying the Foundation for Socialism* (Verso, 2019); Frederic Jameson, *Archaeologies of the Future: The Desire Called Utopia and Other Science Fictions* (Verso, 2005), 153n22; Nick Srnicek, *Platform Capitalism* (Polity Press, 2017), 128.

30
See the websites https://turkopticon.net/ , https://exposing.ai/, and https://politicallymath.in/.

31
Sylvia Wynter, "Towards the Sociogenic Principle: Fanon, Identity, the Puzzle of Conscious Experience, and What It Is Like to Be 'Black,'" in *National Identities and Sociopolitical Changes in Latin America* , ed. Antonio Gomez-Moriana, Mercedes Duran-Cogan (Routledge, 2001). See also Luciana Parisi, "Interactive Computation and Artificial Epistemologies," *Theory, Culture, and Society* 38, no. 7–8 (October 2021).

32
Frank Pasquale, *New Laws of Robotics: Defending Human Expertise in the Age of AI* (Harvard University Press, 2020); Dan McQuillan, "People's Councils for Ethical Machine Learning," *Social Media+ Society* 4, no. 2 (2018).