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VISIONS OF A ROBOT ECONOMY

Contributions from
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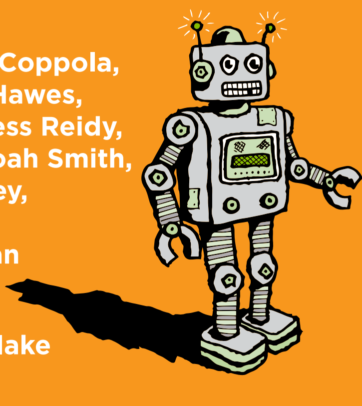

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INTRODUCTION

THE CASE FOR A ROBOT REVOLUTION

STIAN WESTLAKE, NESTA

"The robots are taking our jobs!"

Not long ago, this worry was the stuff of science fiction. Now, as self–driving cars take to the streets and robots fill our warehouses and factories, it is entering mainstream political debate around the world.

This raises important questions for all of us. How society uses new technologies is not a foregone conclusion. It depends on political decisions, cultural norms and economic choices as much as on the technologies themselves.

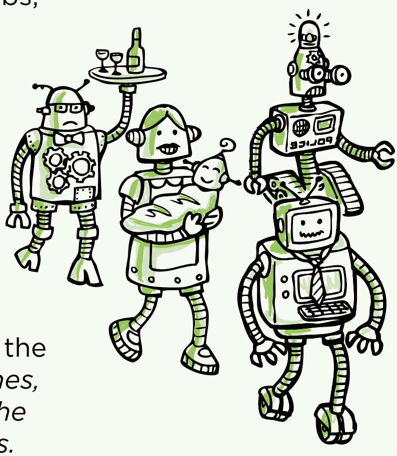
This book looks at the phenomenon of new robot technologies, asks what impact they might have on the economy, and considers how governments, businesses and individuals should respond to them. Because technological change is a complex business, it includes views from a range of disciplines, including economics, engineering, history, philosophy and innovation studies.

THE ROBOT HYPOTHESIS

Few technologies have captured the human imagination like robots. People have been fantasising about robots since long before they became technologically possible. Medieval romances feature a wide variety of walking, talking automata. Androids have been a mainstay of science fiction since the early twentieth century. And now they've entered the public debate in a new role: as agents of profound economic change.

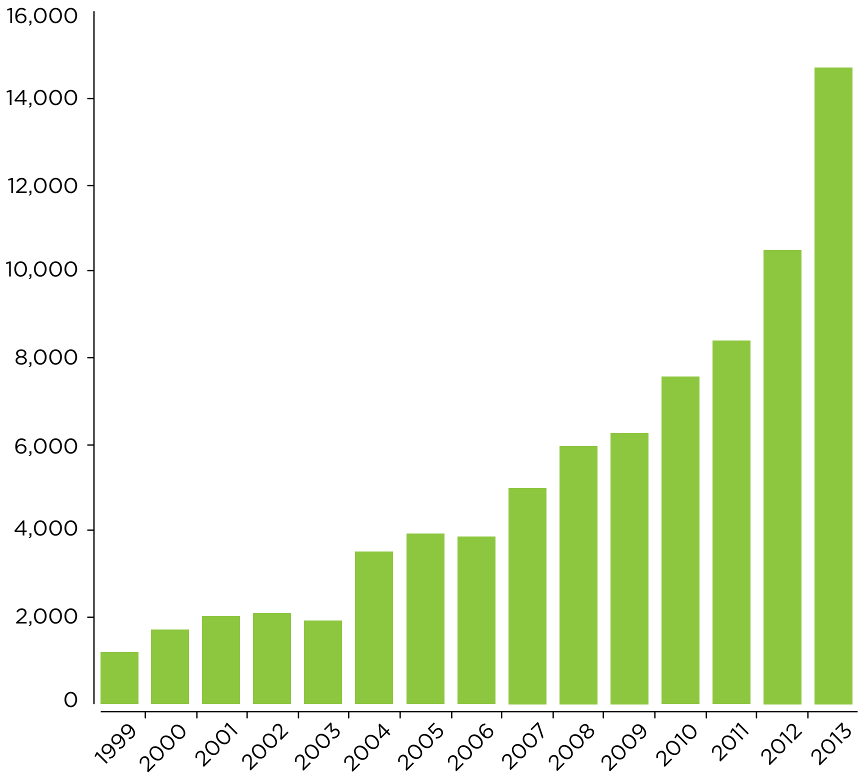
Robots, the argument goes, are learning to do work once only done by humans. This is destroying jobs, and making the rich richer and the poor poorer. Let's call this the Robot Hypothesis.

The Robots Hypothesis ties together two powerful themes in popular culture: the rapid advance of IT, and the startling growth in inequality that has taken place around the world. It's perhaps no surprise that it has become big news: in the last year it has been covered in the *New York Times* and the *Financial Times,* and made it onto the front cover of *The Economist, Newsnight* and *60 Minutes.*



The robots at the centre of the Robot Hypothesis are not traditional tin men. In his essay in this book, Nick Hawes, Senior Lecturer in Intelligent Robotics at the University of Birmingham, defines a robot as *"a machine that automates a physical task".* This include nonhuman robots like self-driving cars, inanimate machines like self-service checkouts and potentially even computer technologies that aren't really robots in any real sense of the word, like software that can analyse medical x-rays or translate English texts into Chinese. Such is the power of the idea of robots that they've come to stand for the whole lot.

FIGURE 1: **HEADLINE MENTIONS OF THE WORD 'ROBOT' IN ENGLISH LANGUAGE NEWS, 1999-2013**



The idea that new technologies are increasing inequality isn't new. In the 2000s, economists began to observe that machines were having an unusual effect on labour markets. Ken Autor, another MIT economist, observed in 2003 that technology was more likely to destroy middling jobs than high-end or low-end ones. In a paper with Frank Levy and Richard Murnane, Autor noted technology was more likely to replace routine work, like bookkeeping or lathing, than non-routine work, like nursing or investment banking, and that routine jobs were more likely to be middle-income ones. So if the machines are doing the routine jobs, we would be left with greater inequality among the jobs that remain. We'd be left with 'lovely jobs' and 'lousy jobs', in the words of Alan Manning, an LSE economist.

And interest has heightened in the current decade. 2011 saw the publication of a bestselling e-book, *Race Against the Machine,* by MIT academics Erik Brynjolfsson and Andrew McAfee, making the case forcefully. Foxconn, the giant Taiwanese manufacturer of Apple products, announced it was planning to deploy a million robots in its factories in China. The next year, Amazon acquired a robotics firm, Kiva Systems, raising the prospect of robots managing the firm's vast warehouses.

Brynjolfsson and McAfee followed up their research with a full-length book *The Second Machine Age*. A striking piece of research from Oxford University suggested that 47 per cent of American jobs might fall prey to technology in the future; the figure for the UK is a not particularly less alarming 36 per cent. And Google got in on the act too, acquiring Boston Dynamics (a manufacturer of military robots whose captivatingly sinister robot dogs and walkers have become a YouTube mainstay) and working to commercialise the self-driving car. The Robot Hypothesis seems here to stay.

ROBOT SCEPTICS

But not everyone agrees that the coming of the robot economy is a problem – either because they see it as a good thing, or because they don't believe it is actually happening.

One argument is that the economy will adapt fairly painlessly to big changes in employment caused by automation. Just as the sons of agricultural labourers made redundant by seed drills and tractors got jobs in factories, and the daughters of factory workers made redundant by faster assembly lines and lean production got jobs in the services sector, so new jobs will arise to make use of the talents of those whose jobs have been taken by robots. Pundits like Tim Worstall are positively enthusiastic about this, arguing that we work to live, not live to work, and should celebrate greater efficiency (although they give relatively little consideration to how this promised land will come to be).

Other sceptics argue that the Robot Hypothesis identifies the wrong culprit: that rising inequality is caused by social and political choices, not by new technologies. Dean Baker, an American economist, argues that the root of American inequality is not automation but *"the rich writing the rules to make themselves richer",* by lowering taxes, scrapping worker protection and cracking down on unions. French economist Thomas Piketty's much–discussed analysis of inequality, *Capital in the Twenty–First Century,* highlights the importance of a class of 'supermanagers' who receive dizzyingly high pay, often as a result of the financialisation of the economy.

What's more, robot sceptics can point to earlier, failed predictions of a robot revolution. People have often worried that technology would lead to the end of work. But as Geoff Mulgan has observed, neither the fears of the Luddites in the 1810s nor of Wassily Leontief in the 1970s, nor of Jeremy Rifkin in the 1990s have actually come to pass. By this logic, we should be relatively untroubled by the Robot Hypothesis, since it could be a false alarm.

But just because inequality has social causes does not mean that technology has not played a role too. And just because previous predictions of job losses from automation have been exaggerated does not mean that robots will not destroy large numbers of jobs in the future.

Frederick Guy's essay in this book points out that technology has played an important role in rising CEO incomes and falling pay for the average worker. The computerised till makes it easier to monitor and discipline a cashier, while the Bloomberg terminal helps enable an economy where the cashier's CEO can claim multi–million pound share options.

Likewise, even if it is true that some or even most of the recent rise in inequality has had little to do with technology, this does not mean that emerging technologies like driverless cars or warehouse robotics will not have major effects on the labour market.

It has become a cliché in some circles to talk about the accelerating pace of improvement in semiconductors and telecommunications, and the rapid adoption of technologies like smartphones, but it is no less true for all that. Information and Communication Technologies look very much like previous general–purpose technologies such as steam power and electrification that transformed the world's economy in the last two centuries.

THE UK: REVOLUTION POSTPONED?

There is one further objection to the Robot Hypothesis that is of special relevance to the UK. It seems that the impact of automation has been lower in Britain than in the United States and perhaps other countries. It may be that the UK has unwittingly become a temporary hold–out against automation. This may not, however, be a good thing.

It has been widely noted that UK median wages have fallen significantly since the 2008 crisis, much more so than wages in the US. At the same time, UK employment has recovered relatively rapidly from the recession, but output has recovered much slower, with the result that productivity has scarcely increased since 2008. Ryan Avent, one of the contributors to this book, has argued that this is a sign of the UK failing to invest in new automation, and instead hiring more workers at lower wages.

This is part of a much older story of UK underinvestment in new technology, which has been widely debated for years, and which many commentators believe is caused by endemic short–termism and poor managerial incentives. But it puts the UK in an unusual position with respect to the putative robot revolution: our employment rates have held up relatively well, as if we had taken a conscious choice to reject out of hand (at least some of) the benefits of automation. But this choice has been far from conscious – indeed, it runs exactly counter to Government aspirations to encourage businesses to invest in innovation – and the net result, less unemployment but woeful productivity, is nothing to be pleased about.

HOW SHOULD SOCIETY RESPOND TO THE ROBOT HYPOTHESIS?

So how should we respond to the possibility that new technologies will make large numbers of workers redundant and increase the gap between haves and have-nots?

FACING THE ROBOTS WITH OPTIMISM

We can start by adopting an optimistic frame of mind. Technology is not destiny, even though some of its more breathless prophets claim it is. The effect that technology has on society is as much a function of human choices – about politics, business organisation, and social norms – as it is a function of the properties of the technologies themselves.

The distinguished innovation scholar Carlota Perez argues that when a major new technology comes into the world, what really shakes things up is the change of *"techno-economic paradigm"*, the suite of principles, rules and institutions that society puts in place around the new technology to make use of it.

Consider electric power: the impact of electrification was a huge technological breakthrough, but it depended on countless social decisions and deployments to have any real effect. From the redesign of factories so that each machine had its own power source, revolutionising industrial organisation, to the deployment of labour saving devices in the home and the effect on women's work and women's rights, these were profoundly social phenomena, and depended on people's conscious choices.

People face similar choices when it comes to robots. As voters, customers and workers, our actions influence how institutions will respond to new technologies of automation, what measures are taken to protect those put out of work by them and how society shares the rewards.

This theme emerges in several of the essays in this collection – Noah Smith and Frances Coppola both stress the importance of political decisions in the impact of automation. Georgina Voss shows how the relative position of women and men in a robot future will depend on social as much as on technological decisions. The importance of the social context of technology emerges even more strongly when we look at accounts of the distant past and the future. ER Truitt's piece shows that social discussions about robots abounded in the Middle Ages, long before modern robots existed, while Jon Turney's account of robot economies in science fiction novels shows how different sci-fi authors worked through the social possibilities of automation and abundance.

The message from all of this is that technology may change the solution space within which we operate, but it is humans who make the ultimate decisions – and you should distrust anyone who tells you otherwise.

So proceeding in a spirit of optimism, we can identify a few areas where public policy can help us make the most of the promise of automation – and avoid a robotic dystopia.

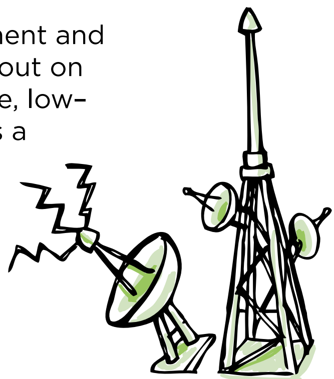
MAKING THE MOST OF THE UPSIDE

It's fashionable to mock mainstream economic models of technology change, which often imply that technology is homogeneous and always beneficial, but they have some things going for them. All other things being equal, it would be very welcome if we could automate large amounts of drudgerous work and free people up to do more creative, enjoyable, ennobling things with their time. A major aim of government policy with regard to automation should be to help make this happen.

And there will surely be things left for humans to do. Several of the authors in this collection make the point that there will certainly be important work left to be done even if large swathes of the economy are automated. Frances Coppola makes the point that activities like social care and the creative industries are likely to rely on skills that robots find hard to emulate. Izabella Kaminska and Edward Skidelsky highlight the opportunity to make the work that remains more intrinsically rewarding.

There are two challenges to achieving this, at least from a British perspective.

The first is how to make sure underinvestment and short-termism do not cause the UK to miss out on the robotic revolution entirely. The low-wage, low-productivity trap identified by Ryan Avent is a way of avoiding a robot dystopia, but a very unsatisfactory one – the UK might resist a short-term rise in inequality from automation, but we will suffer in the medium term as our productivity stagnates, the traded parts of our economy lose out to foreign competition, and everyone becomes poorer.



Encouraging the adoption of new technologies will require us to tackle British investors and managers' reputation for short–termism – most likely by better corporate governance – and to increase the availability of long–term patient capital. If the private sector cannot provide this, it may have to come from the public sector, after the manner of the German Kreditanstalt für Wiederaufbau development bank or the US Small Business Administration.

It will also require a sensitive approach to regulation. We must be willing to experiment with regulations, perhaps in designated areas or for limited times, to understand how new technologies can be deployed safely and effectively. Several governments have announced self–driving car test–beds; we also need test–beds and trials for artificial intelligence medical diagnostics, automated fraud detection, drone traffic enforcement, and so on. Government's role here is to create safe spaces to experiment, to fund or co–fund research in the public interest, and to stop incumbents from stonewalling new, high–tech competition.

Public policy also has a role to play in making sure that the new, non–robot jobs emerge, and that people have the skills necessary to do them.

Human jobs in a robot age are those that require skills that are hard for robots to develop, such as creativity, empathy and social skills. Many of these jobs exist in sectors that have a mixed track–record at innovating, or which face their own challenges from technology. How do we create high–skilled, fulfilling social care jobs, given the public funding of much of the social care sector and constraints on public finances? Will the difficulty of making money from creative content in an age of free online copying make it hard for people to find work in the creative industries?

One response to this is to improve our education system. Children should be learning to work creatively with technology, to be 'digital makers' (schemes like Make Things Do Stuff and the Studio Schools movement offer examples of what could be achieved). The demands of a robot economy also lend support to the growing movement to teach non–cognitive skills, like determination or resilience, which inform social interactions.

Government should also consider drafting industrial strategies for sectors likely to create jobs in the robot age, such as the creative industries and social and personal care. Like the Government's existing industrial strategies, these strategies would consider skills needs, access to finance, the role of public procurement, and research and development funding. It is ironic that, while all three main UK political parties are supportive of the idea of industrial strategy, we have strategies in various manufacturing and logistics sector, but not in the creative industries (where the UK is genuinely distinctive) or in health and social care (where government procurement and regulation play a very significant role).

SPREADING THE BENEFITS

Of course, distribution matters too. If the benefits of robot technologies go mostly to a small minority, it is legitimate for voters and government to demand a fairer division of the spoils. Steve Randy Waldman notes that societies where a few people own the majority of the wealth have a nasty habit of developing bad political institutions – the so-called resource curse that crops up time and time again in history of oil-rich states.

The essays in this volume address a number of possibilities for how the proceeds of a robot revolution might be redistributed. Notably, Noah Smith's piece argues for a universal basic income for everyone, paid for from the proceeds of robot-enhanced productivity.

What is clear is that if automation necessitates a big shift in how we tax, it offers an opportunity to start taxing more sensible things. Economists have long argued for taxing land, carbon emissions and other bads, rather than taxing work. If there is less work about in the future, this may be the chance to make a change.

There is also the question of how we share out the rewards of a robot economy. We may not yet be ready for a universal basic income, since at least for the time being so many people's conception of (their own and others') value to society is bound up in work. But it is surely worth making policies to encourage ownership of robots is widely dispersed. The simplest way to make sure everyone has a stake in robots is to encourage widespread pension ownership – so that people own shares in the companies that own the robots.

But if the riches of automation are really as abundant as some people think they are, we could go further, and learn a lesson from the few countries that have dealt well with natural resource riches, like Norway and Alaska, by establishing a national endowment to hold wealth on behalf of citizens. The proceeds of this could be used to pay an annual dividend to citizens (as in Alaska) or to invest in future productivity (as has been proposed in Norway).

WATCHING THE DOWNSIDES

The third role for government is to be wary of uses of automation that are downright bad. Most of the examples of robot technology we have considered in this book are good for society in aggregate, but bad for some people – typically the people whose jobs they replace. But there is of course a subset of technologies whose overall impact is negative.

With the benefit of hindsight, we can see that innovations like tetraethyl lead were on the whole bad for society. In an age of increasingly intelligent machines, it's easy to imagine more innovations that bring small benefits to a few but large downsides to an equal or greater number. Fixed–odds betting terminals and high–frequency trading algorithms have both come under scrutiny recently; enabling these and similar technologies with greater intelligence and power could lead to even greater and more justified concerns.

It is hard for governments – or indeed for anyone – to accurately diagnose whether an innovation is sufficiently bad to ban. But politicians should encourage an open and informed debate about it, backed up with the capability to regulate effectively if necessary, and approach that researchers like Richard Owen and Jack Stilgoe have called 'responsible innovation'.

What all of this comes down to is that the UK and its government should approach the challenge of the robot economy with optimism, on the condition that we engage with it on two fronts. On the one hand, we should enthusiastically support investment in new technologies of automation, and challenge both British short–termism and the vested interests of incumbents who might oppose technological competition. On the other hand, politicians should vigorously engage with the human side of the robot question, aggressively working to encourage job creation in fields where human skills still reign supreme, and reforming our tax and pension system to spread the wealth created by the robot economy widely.

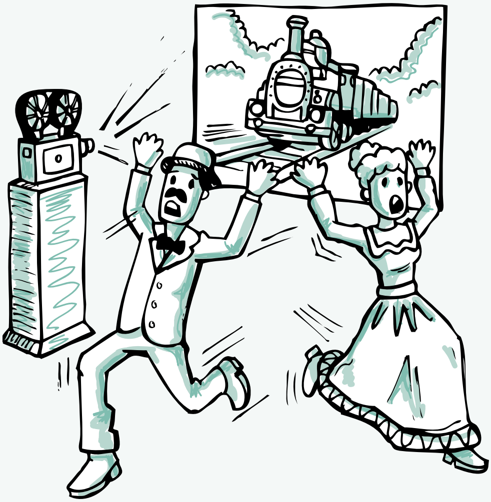
In short, we must embrace the robots, but do so with humanity.

PART 1.

THE ECONOMICS OF A ROBOT FUTURE

THE REVOLUTION WILL BE UNCOMFORTABLE

RYAN AVENT



Pessimists of the innovation potential of modern economies often cite something called the kitchen test to sway the casual sceptic. Think of kitchens a half decade ago, the thought experiment runs, and one comes up with a recognisably modern image. There is indoor plumbing, certainly, refrigeration, basic appliances, and perhaps a microwave and a television. Productivity in the kitchen in the 1960s was about what it is today. Go back another half century, however, and the typical kitchen looks vastly different. There were no electrical appliances to speak of. Refrigeration might well have come in the form of an icebox, and water, in many cases, had to be brought in from outdoors. One need not dig into rates of patenting or productivity statistics to know that innovation has slowed, the experiment suggests: simply trust the evidence of one's own senses and the absence of life-improving new gadgets.

But there is another way of looking at the kitchen test. In an important way, innovation sceptics have sold the kitchen innovations of the first half of the twentieth century short. The biggest impact of kitchen productivity enhancements came not inside the kitchen but outside of it.

Just 25 per cent of married women worked outside of the home in 1950. By 2000 that figure had risen to 60 per cent. According to one estimate nearly half of that increase can be attributed to the labour-saving effects of household appliances. Freed from the need to specialise in what economists call 'home production', married women could move into the wage economy: a shift with momentous social consequences.

Many of those consequences were unambiguously positive. It began a process in which women were extended the same opportunities in the labour force as men. That meant terrific improvements in the individual welfare of women long stifled by the economic and cultural demands of early twentieth century society. It also helped unleash an important boom in the economy's stock of labour and human capital: particularly as rising female labour–force participation encouraged rising female educational attainment.

But change did not occur easily. For those whose positions of privilege were challenged, the entry of millions of women into the workforce was an uncomfortable experience. Domestic life changed, requiring much of society to reset its expectations about who should do what where. And the rise of the working woman required institutional change that often occurred slowly, and after long struggles: changes to laws and regulations, to company policies and office norms.

While the kitchen gadgets whirred, their arrival echoed across society as the world adapted itself to the new possibilities those gadgets enabled. The kitchen test suggests a rule of thumb: the placid society is stagnating technologically. Powerful technologies bend society around them, as people and institutions adjust to maximise the potential of the new inventions. Those adjustments disturb old societal patterns and break old links. Rapid technological change leaves a tell–tale residue of social disruption.

This dynamic is most plain in the great era of industrialisation in the early nineteenth century. To say that Western Europe in the era before the Industrial Revolution was a paradise of working–class autonomy would perhaps be overstating matters. State, church, and culture limited independence, as did economics. Yet at the time society in places like Britain and the Netherlands was free in ways that you or I have never really known. Workers were free in the sense that they were, to a remarkable extent, the fundamental units of production in the economy, a status that gave them a surprising amount of choice about how to live their lives.

Production was organised in several different ways on the eve of the revolution. There were independent producers, including skilled craftsmen. There was cottage industry as it is commonly understood, in which individual workers produced goods for a business–owner, from the comfort of their home and for piece rates: they were paid, in other words, by the quantity of a good produced. There were even 'manufactories', where workers gathered in one place to use resources and equipment owned by a single firm or capitalist.

Yet within these organisational forms the individual worker and the tools that worker used embodied the whole of a particular production process. As a result the individual worker enjoyed enormous freedom. He or she could work from home, for instance: could rise whenever it suited, work as hard or as lackadaisically as desired, even drink or indeed get drunk on the job. Dutiful or productive workers would earn more than lazy workers. But 'dutiful and productive' did not equate to behaving in a particular and prescribed way. Nor was it a major work requirement.

Between the late eighteenth century and the late nineteenth century that sort of industry was almost entirely swept away. It took with it a conception of society vastly different from what you and I now know. The Industrial Revolution turned man from wielder of machine to part of the machine. To be more specific, work began to involve the coordinated use of capital equipment in order to operate at significant scale, the better to reap enormous productivity gains: big buildings, big staffs, big machines, big cities, big money.

By the end of the transition production was overwhelmingly done outside the home. It was done in plants, in which ownership of building, capital equipment, and material used was all concentrated in the hands of one or a few capitalists. Commuting to work became the norm. Workers worked set hours at a pace set by the factory owner, and they were paid according to the time worked rather than by the finished piece. What's

more, production required precision: in terms of skills applied and sobriety, as well as in the quality of the finished product. Capital demanded it, the better to wring the highest return out of massive, expensive new machinery, and to produce as much of a uniform product as possible as efficiently as possible.

These forces generated profound social and cultural changes. The capitalist class required a large pool of docile, sober, and reasonably well–educated (meaning at least literate and numerate) labour. Such concerns drove broad societal pushes for regularised and public education, for moral instruction and temperance, even for a sense of pride and belonging to something greater than the individual.

The social milieu of the typical worker also changed enormously. Daily routines became far more rigidly constructed. Commuting, eating and drinking, and other entertainments were increasingly subjugated to the workweek. Home work was replaced by tightly scripted line–work in a plant, where tasks were monitored and goofing around strongly discouraged. And industrial economies operated at a vastly different metropolitan scale. The expense of moving goods and the value of vast labour pools militated in favour of great cities, with populations in the millions rather than the tens of thousands.

These changes took place over the course of a century. Nevertheless, the transformation of modern society was sufficiently rapid and dramatic to generate great social and political upheaval: above all a sense of alienation that facilitated profound social change, to benign ends in some cases – in art, for instance, and in the development of political movements aimed at improving the lot of society's worst off, investing in education, and protecting the environment – and highly unfortunate ends in others. Ambitious and deadly political innovations like communism and fascism took as their fuel the tens of millions of new residents of industrialised metropolises.

It is remarkable, when one reflects on it, to consider the social power of a thing like the steam engine. A few fundamental inventions created the opportunity of higher productivity. But to take best advantage of that potential society had to transform itself from top to bottom. And with scarcely a moment's hesitation it did it, knocking new institutions and norms into place along the way, as if they, too, were a part of the machinery on the factory floor.

No single invention may be as powerful, on this metric, as the car. For thousands of years cities were constrained in size by the distance an individual could walk on his own two feet. Horse–drawn conveyances could take a man farther, faster, but horses needed significant care and food and left piles of dung everywhere they went. City boundaries stretched outward with the introduction of streetcars and urban rail in the nineteenth century. But most transit was slow and limited in geographical range, while faster subways were hugely expensive to build.

Then along came the automobile. But not all at once. An automobile like the Model T was a device with enormous potential. But much of that potential wasn't easily realised. A top speed of 40 miles per hour was all but useless on urban streets thronged by pedestrians. Without hard, flat roads to drive on, a potential range of 170 miles was meaningless; there was nowhere to go. Reliability was reassuring but scarcely mattered without easy access to affordable fuel. The technological power of the automobile was not an inherent part of its design but resulted from its ability to bend society around it until it conformed to its preferred shape.

That process began immediately but unfolded over a century. Markets did some of the work. The automobile's demands led to development of broad new swathes of economic activity. Gas stations sprouted up, as did auto repair shops, tyre merchants, roadside inns and diners, and drive–in theatres. The government took action, building roads and highways, and providing rules of the road and traffic enforcement.

Society's very shape began to change. Cities grew outward to take advantage of the automobile's range. Homes and yards grew in size, no longer constrained by tight urban environs. New cities grew up well away from the rivers and harbours that had once been indispensable to metropolitan economic life. Business models changed. The rise of trucking forever altered the economics of domestic freight transport. Big box retail outlets surrounded by a sea of parking created huge efficiencies and passed the savings on to consumers.

The automobile altered American culture. It changed conceptions of individual independence. It normalised society to the death or injury each year of tens of thousands of people behind or under the wheel. The rapid suburbanisation it fuelled supported a high middle–class quality of life – but also enabled segregation: de jure in the South, de facto across America. And through these alterations and others the automobile bent American history and politics and economics into the form we now recognise (with more limited but still profound change resulting elsewhere in the rich world).

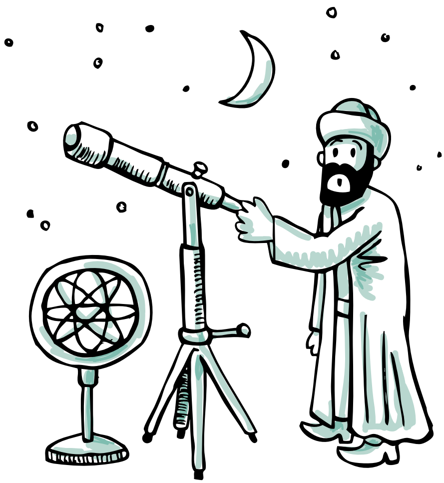
The car's power as an invention was not in its performance advantages relative to the carriages and streetcars it displaced. The car's phenomenal power is in the way those advantages generated a societal response: economically, culturally, geographically. The evidence of technological stagnation in transport is all around us; we continue to live in the world we made for the car.

Comparing one invention with another, rather than the forces they exert on society, can lead one astray. Economist Robert Gordon, a sceptic of the transformative potential of recent innovations, poo–poohed the possibilities of autonomous vehicles in a 2012 Wall Street Journal essay, writing:

> *“People are in cars to go somewhere, whether from home to work or from home to shop. Once they are inside the car, there is relatively little difference between driving the car on their own or having it drive itself. Greater safety? Auto fatalities per million miles traveled have already declined by a factor of ten since 1950.*
>
> *In setting out the case for pessimism, I have been accused by some of a failure of imagination.”*

Gordon is right: making a car driverless does very little for its performance relative to the non–autonomous version. But that is the wrong way to assess the importance and potential of the driverless vehicle.

It is no stretch of the imagination at all to think that within a few years more the dream of a stupendously reliable driverless car will have become a reality. That reality would represent a revolutionary improvement over the status quo. Driverless cars could travel faster, farther,



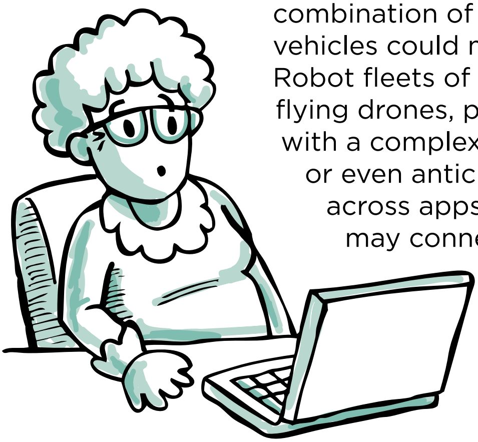
with many fewer accidents. Gordon's dismissiveness regarding the safety improvements possible under autonomous technology is wildly off–the–mark. Some 30,000 people die in car accidents each year in America alone. Many more are injured. The cumulative economic cost is astounding.

But while safety improvements are economically important, they fall short of revolutionary. Few people stay off the road now because of the danger of driving.

Autonomous vehicles can manage much more than life–saving, however. They could eliminate traffic. They could, in fact, eliminate traffic signals. Both road and car designs could change in response, minimising their footprints and expense. Driverless cars could take many more journeys than people alone demand (or could take journeys without people that people would otherwise need to take). Cities may well become a hive of drone activity, with delivery vehicles of all types and sizes ferrying goods around. People too, but mostly goods.

It is difficult to know how human behaviour might change as a result. When the cost or inconvenience of something falls, people tend to do much more of it. Driverless cars could bring out the recluse in all of us by allowing us to have a world of goods at our door, double–quick at the touch of a button. But it might also or instead make us more social if, say, the marginal trip is a night out or a visit to the city, which we decline as a result of the hassle of driving, sitting in traffic, and parking. Or perhaps people will work more, as commuting loses its sting.

The power of autonomous vehicles could be multiplied by the emergence of complementary technological systems. The combination of 3D printing with driverless vehicles could make warehousing obsolete. Robot fleets of autonomous vehicles – and flying drones, perhaps – may move in parallel with a complex online world, responding to or even anticipating the desires we express across apps and social networks. They may connect directly with our offices and houses; our refrigerators may remain fully stocked, seemingly of their own accord.



As these changes occur the physical geography of the world will be altered. People will live in different ways and in different places. The use of land across large portions of metropolitan areas may be rendered obsolete. As these developments occur societal norms will adjust. Some of that adjustment will be fuelled by the alienation that inevitably accompanies so dramatic a change in our world. New economic and political movements will arise, to reckon with the new world, to help us accommodate ourselves to it, and because some people see profit or power to be had in the interaction between economic and social change. We can speculate about what that world will look like, so long as we don't mind being wrong.

What is fairly certain is the inevitability of great societal change in response to great technical change. From one perspective the world of driverless vehicles seems gravely in doubt, threatened on all sides by incompatible rules and regulations. From another it seems mostly boring, not much more important than cruise control or the automatic transmission. Both perspectives are almost certainly mistaken. Because it is not boring, its future is not imperilled by unfriendly institutions. The great innovations insinuate themselves into our lives, combine with their peers, and warp society like a powerful gravitational field.

Correspondingly, a society in the throes of rapid technological and economic change is one in which old orders rapidly and chaotically give way to new ones. It has been long enough since the most dramatic years of the industrial era that most of us cannot remember what that is like. The generation of retiring baby boomers came of age as the social tumult unleashed by the industrial revolution shuddered its last.

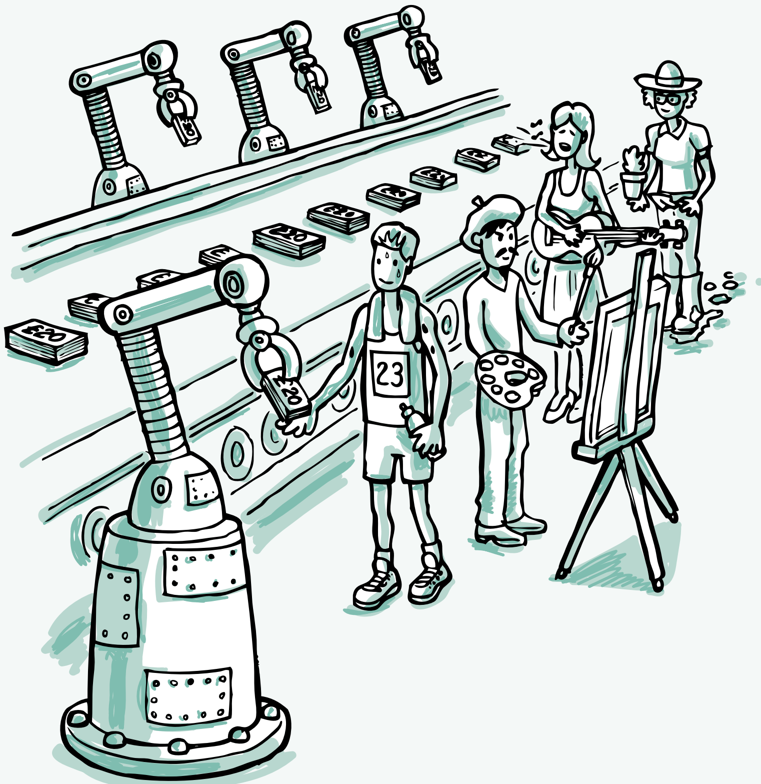
Accelerating technological progress means that an unfamiliar process awaits us. The economic transformation will be exciting, carrying the possibility of great improvement in living standards. But we will measure its progress in our own discomfort.

THE END OF LABOUR: HOW TO PROTECT WORKERS FROM THE RISE OF ROBOTS

NOAH SMITH

Technology used to make us better at our jobs. Now it's making many of us obsolete, as the share of income going to workers is crashing, all over the world. What do we do now?

Here's a scene that will be familiar to anyone who's ever taken an introductory economics course. The professor has just finished explaining that in economics, 'efficiency' means that there are no



possible gains from trade. Then some loudmouth kid in the back raises his hand and asks: *"Wait, so if one person has everything, and everyone else has nothing and just dies, is that an 'efficient' outcome?"* The professor, looking a little chagrined, responds: *"Well, yes, it is."* And the whole class rolls their eyes and thinks: Economists.

For most of modern history, inequality has been a manageable problem. The reason is that no matter how unequal things get, most people are born with something valuable: the ability to work, to learn, and to earn money. In economist–ese, people are born with an 'endowment of human capital'. It's just not possible for one person to have everything, as in the nightmare example in Econ 101.

For most of modern history, two–thirds of the income of most rich nations has gone to pay salaries and wages for people who work, while one–third has gone to pay dividends, capital gains, interest, rent, etc. to the people who own capital. This two–thirds/one–third division was so stable that people began to believe it would last forever. But in the past ten years, something has changed. Labour's share of income has steadily declined, falling by several percentage points since 2000. It now sits at around 60 per cent or lower. The fall of labour income, and the rise of capital income, has contributed to America's growing inequality.

WHERE IS THE MONEY GOING?

What can explain this shift? One hypothesis is: China. The recent entry of China into the global trading system basically doubled the labour force available to multinational companies. When labour becomes more plentiful, the return to labour goes down. In a world flooded with cheap Chinese labour, capital becomes relatively scarce, and its share of income goes up. As China develops, this effect should go away, as China builds up its own capital stock. This is probably already happening.

But there is another, more sinister explanation for the change. In past times, technological change always augmented the abilities of human beings. A worker with a machine saw was much more productive than a worker with a hand saw. The fears of Luddites, who tried to prevent the spread of technology out of fear of losing their jobs, proved unfounded. But that was then, and this is now. Recent technological advances in the area of computers and automation have begun to do some higher cognitive tasks – think of robots building cars, stocking groceries, doing your taxes.

Once human cognition is replaced, what else have we got? For the ultimate extreme example, imagine a robot that costs $5 to manufacture and can do everything you do, only better. You would be as obsolete as a horse.

Now, humans will never be completely replaced, like horses were. Horses have no property rights or reproductive rights, nor the intelligence to enter into contracts. There will always be something for humans to do for money. But it is quite possible that workers' share of what society produces will continue to go down and down, as our economy becomes more and more capital–intensive. This possibility is increasingly the subject of discussion among economists. Erik Brynjolfsson has written a book about it, and economists like Paul Krugman and Tyler Cowen are talking about it more and more (for those of you who are interested, here is a huge collection of links, courtesy of blogger Izabella Kaminska). In the academic literature, the theory goes by the name of 'capital–biased technological change.'

The big question is: What do we do if and when our old mechanisms for coping with inequality break down? If the 'endowment of human capital' with which people are born gets less and less valuable, we'll get closer and closer to that Econ 101 example of a world in which the capital owners get everything. A society with cheap robot labour would be an incredibly prosperous one, but we will need to find some way for the vast majority of human beings to share in that prosperity, or we risk the kinds of dystopian outcomes that now exist only in science fiction.

REDISTRIBUTION AGAINST THE MACHINE

How do we fairly distribute income and wealth in the age of the robots?

The standard answer is to do more income redistribution through the typical government channels – Earned Income Tax Credit, welfare, etc. That might work as a stopgap, but if things become more severe, we'll run into a lot of political problems if we lean too heavily on those tools. In a world where capital earns most of the income, we will have to get more creative.

First of all, it should be easier for the common people to own their own capital – their own private army of robots. That will mean making 'small business owner' a much more common occupation than it is today (some would argue that with the rise of freelancing, this is already happening). Small businesses should be very easy to start, and regulation should continue to favour them. It's a bit odd to think of small businesses as a tool of wealth redistribution, but strange times require strange measures.

Of course, not all businesses can be small businesses. More families would benefit from owning stock in big companies. Right now, America is going in exactly the opposite direction, with companies going private instead of making their stock available for public ownership. All large firms should be given incentives to list publicly. This will definitely mean reforming regulations like Sarbanes–Oxley that make it risky and difficult to go public; it may also mean tax incentives.

And then there are more extreme measures. Everyone is born with an endowment of labour; why not also an endowment of capital? What if, when each citizen turns eighteen, the government bought him or her a diversified portfolio of equity? Of course, some people would want to sell it immediately, cash out, and party, but this could be prevented with some fairly light paternalism, like temporary 'lock–up' provisions. This portfolio of capital ownership would act as an insurance policy for each human worker; if technological improvements reduced the value of that person's labour, he or she would reap compensating benefits through increased dividends and capital gains. This would essentially be like the kind of socialist land reforms proposed in highly unequal Latin American countries, only redistributing stock instead of land.

Now of course this is an extreme measure, for an extreme hypothetical case. It may turn out that the 'rise of the robots' ends up augmenting human labour instead of replacing it. It may be that technology never exceeds our mental capacity. It may be that the fall in labour's income share has really been due to the great Chinese Labour Dump, and not to robots after all, and that labour will make a comeback as soon as China catches up to the West.

But if not – if the age of mass human labour is about to permanently end – then we need to think fast. Extreme inequality may be 'efficient' in the Econ 101 sense, but in the real world it always leads to disaster.

AUTOMATION AND JOBS: COMPETITION OR COOPERATION?

FRANCES COPPOLA

***"Robots will take all our jobs! We will all starve!"* cry modern-day Luddites faced with the fastest pace of automation since the Industrial Revolution. Their argument is that humans compete unsuccessfully with robots and computers for work. As jobs are automated, so humans will become redundant.**

Those who design, develop and operate the automated systems of the future may be very well paid. But those who are displaced by automated systems face a bleak future. The only way they can continue to work is if they are paid less than the cost of automation. Therefore, the wages of people whose jobs could be automated will fall below the cost of automation.

But there is an alternative view. Automation offers a real opportunity to change the way we work, and even the way we live. For the first time in history, people have the real prospect of no longer having to work long hours in boring, repetitive and physically debilitating jobs to meet basic needs. We can have more time to spend interacting with each other, caring for each other, and creating beautiful things and clever ideas to brighten up people's lives.

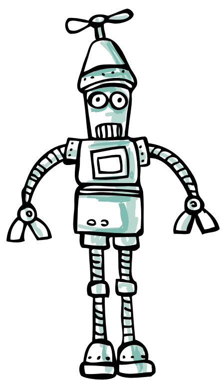
And since abundant production will mean the prices of basic goods will be very low, we will be both willing and able to pay those with skills in personal service and creative industries for their time and attention. People's remuneration will relate to their enhancement of the lives of many people, not their ability to make profits for a few.

The Luddite argument appears persuasive. The impact of technological change on the labour market is already considerable, although offshoring and immigration also play a part. We are already seeing falling real wages for those at the bottom end of the income spectrum, coupled with hollowing-out of the middle as routine medium-skilled jobs are automated.

People with medium skill sets are forced down into lower-skill occupations, in turn forcing out those with poorer skills: it is no surprise that the incidence of long-term unemployment is highest among the unskilled, even in areas where there are unskilled employment opportunities. In fact when faced with a glut of labour, employers tend to 'raise the bar' by insisting on higher skills than are really needed for the job: this reduces the chances of employment for the genuinely low-skilled still further. Competition for low-skilled jobs, coupled with the need to keep wages in low-skill jobs below the cost of automation, ensures that wages do not rise at the pace of those in high-skill occupations – indeed they may even fall, if government routinely 'tops up' low wages with benefits.

The disappearance of routine skilled jobs, the scarcity of high-skilled workers and the substitution of low-skilled workers for more expensive machines causes the labour market to bifurcate. Mean and median wages gradually diverge, as low-skill wages are held down while high-skill wages continue to rise. The employment profile across skill sets starts to resemble an hourglass – bulges in high-skill and low-skill jobs, with a narrowing waist where medium-skill jobs are disappearing.

As more and more people are forced out of medium-skill jobs into low-skilled jobs, working hours decrease: there is more part-time, casual and temporary work. Employment becomes more insecure as a relative glut of labour at the low-skill end of the employment spectrum enables employers to hire and fire at will: there is increasing use of temporary, self-employed and zero-hours contracts as employers seek to avoid employment legislation that limits their hiring and firing autonomy, and workers are forced to accept disadvantageous contracts or face unemployment, or – if they are already unemployed – loss of benefits. At the low-skill end, the balance of power is considerably skewed towards employers.



Conversely, workers with scarce skill sets have considerable negotiating power and can command high and rising wages. Employers express concern that they will not be able to get the skills they need at a price they can afford, and lobby government to change the education system to provide more workers with the skills they require. Universities respond to this need by offering more, and more diverse, courses: but the extent of graduate unemployment, and the proportion of graduates forced into unpaid internships or low–skill jobs suggests that changes in university education alone do not meet the need.

In a free market, falling automation costs and increasing competition for scarce jobs would eventually drive down low–skilled wages to starvation levels, especially in countries that don't have state safety nets. There could be starvation in those countries that have built their recent industrialisation on providing cheap labour for routine production jobs, as falling automation costs make even their low wages uncompetitive. But most Western governments have minimum wage legislation that sets a floor on wages. As the cost of automation fell, therefore, it would become uneconomic in developed countries to employ humans to do jobs that could be automated, even at minimum wage levels. We would expect this to show up as rising structural unemployment.

Some jobs will indeed disappear for ever. For example, assembly line workers are already a dying breed: tomorrow's assembly lines will be remotely operated and require very little human intervention. Driverless cars and GPS may make taxi drivers obsolete. There may be very few manufacturing jobs in the future, and routine service jobs may largely disappear too (supermarket checkout operators, for example).

Those whose skill sets are entirely oriented towards the jobs that are disappearing may find themselves both unemployed and unemployable. And there could be a lot of these people. As we have seen in the past when large dominant industries have died (the Sheffield steel industry springs to mind, but there are many other examples) it can be very hard for people to accept that their skills are no longer required, and retrain for work that is unfamiliar or they consider beneath them.

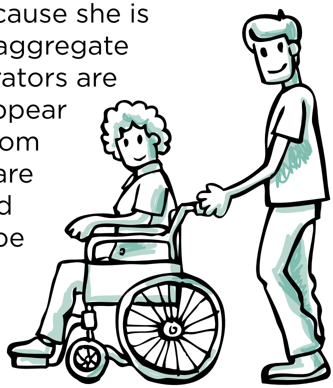
In previous eras of technological change resulting in traditional jobs disappearing, there have been strikes, campaigns and lobbying aimed at preventing the technological changes taking hold. At the extreme there have been riots and destruction of the hated technologies. It is possible that robots could become the focus of such action.

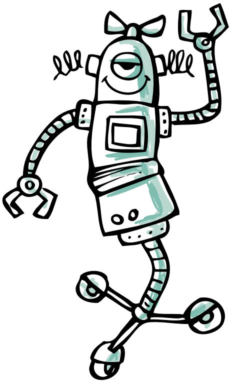
Such social unrest is likely to elicit a government response. As medium– and low–skill jobs become scarcer, governments may provide explicit incentives to firms to employ people rather than automating. This would be regressive: history shows that in the long run, technological change always benefits people. Automation of production enabled families to survive without children's labour, because the price of goods produced with the new machinery was so much lower than those produced in a more labour–intensive way. And automation of housework facilitated the entry of women to the workforce.

In the short term automation causes hardship, as people whose livelihoods depend on the old way of doing things lose their jobs: but in the longer term there is benefit to society in the reduced cost of goods that enable many people to work less, and in the development of new industries to employ those people no longer needed in the old ones. There is no reason to suppose that this time would be different. Legislation to prevent or limit technological change therefore would be short–sighted. An alternative might be for government to provide jobs for anyone who wants them, perhaps coupled with a softer line on benefits to enable people to do socially beneficial, creative and/or entrepreneurial things that don't necessarily earn them a living.

But mass unemployment – or mass starvation, in countries that don't have safety nets – is not the only possible outcome of the era of automation. There is another way.

Automation itself does not deny people jobs. We are already used to using computers as tools to perform dull, long–winded and routine tasks. The office administrator does not lose her job because the computer is doing things she used to do: on the contrary, she becomes more productive because she is working in partnership with a computer. In aggregate that might mean that fewer office administrators are needed – though they are not likely to disappear completely. We are a very long way away from fully automated offices, and as workforces are increasingly dispersed around the world and linked by virtual networks, there may even be a greater need for people to manage and coordinate day–to–day business activities. Some jobs may simply change, rather than disappear.





But the unexpected always happens, and humans are very much better at dealing with the unexpected and thinking up innovative solutions to problems than machines are.

And this offers an exciting prospect. We do not have to compete with technology. We can work in partnership with it – and the result will be greater productivity and more innovation.

Working in partnership with machines, humans will have far more opportunity to use their creative and problem-solving capabilities than they do when most of their time is taken up doing boring routine jobs. A world where many employees are unhappy in their jobs is not as productive as it could be. Studies show that bored and unhappy people are less productive at work, more likely to take days off sick and more likely to retire early due to ill-health. If technological change can enable people to do things they enjoy, productivity should increase dramatically.

Technology makes it easier to work. Technological advancements should increase the workforce, as people with health and disability problems are able to enter the workforce supported by assistive technology and a more flexible approach from employers to working hours and places. Many of these people will have skills that employers desperately need. It would be extremely short-sighted of employers to allow obsolete notions of how people 'should' work to deprive them of skilled people. Now that the internet makes it possible for people to communicate with each other instantaneously all over the world, 'presentee-ism' (if you aren't in the office you aren't working) and the standard 9 to 5 working day must become a thing of the past. For high-skilled people, virtual offices, international networks and flexible hours will become the new standard.

The importance of work for human dignity should not be underestimated. If technological advancement can make it possible for people to work who currently can't, it is without question a good thing. But it is possible that the same technological advances that make it possible for high-skilled people with disabilities to work, may result in medium- and low-skilled people being unable to work.

So will technological advances lead to more jobs overall? Or will bifurcation of the labour market continue to the point where mass unemployment and/or starvation wages create social unrest? This depends on two things:

1. How willing people are to give up the expectation that work will be routine but secure, in favour of more exciting and innovative opportunities that carry the risk of failure.

2. How good the education system is at developing the technology-savvy people that will be needed in the future.

We are already seeing work becoming more uncertain. No-one now expects to leave school, go into a job and stay there until they retire, as was commonplace in the post-war generation. Most people expect to change jobs frequently during their working life, and increasingly people don't just change their jobs, they change their careers, studying and retraining at various stages in their life as their interests, needs and opportunities change. Education, formerly regarded as a young person's game (with maybe a second flush among the newly retired), is becoming a lifelong process.

The nature of employment is changing, too. Traditional full-time jobs are declining, and there is substantial growth in part-time, temporary and self-employed work. Many people now rely on a portfolio of part-time, temporary and casual jobs to provide them with a sufficient income. The distinction between work and leisure is becoming increasingly blurred as people make money from hobbies and do socially beneficial work for nothing.

We are perhaps seeing the beginning of a shift in attitude: instead of having a job, many people are using their skills creatively in a range of activities that collectively generate enough income to meet their needs....but are otherwise indistinguishable from other activities that are unpaid.

The future will require people who are comfortable with technology. Because of this, there are calls for education to emphasise maths, science, technology and engineering, at the expense, particularly, of the creative arts. This is extremely short-sighted. Excellence in technological design requires artistic talent as well as scientific know-how.

Just as humans do not need to compete with robots, so the sciences do not need to compete with the arts. Both will be required to meet the needs of the technology-dominant society of the future. And play, currently undervalued both in primary and secondary education, must become a core part of education. Becoming really comfortable with both technology and the arts is best done through creative play.

The humanities will also be important. Not everyone can design the technologies of the future. The future of work for many people lies in service industries. Education must help people develop social skills and emotional intelligence: community service may become part of mainstream education. The much maligned 'media studies' will grow in importance as communication technology becomes ever more dominant, shaping markets and creating demand for abundant products.

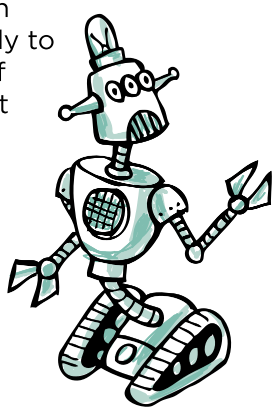
The ability to sell, already a skill for which employers will pay large amounts, will become even more important. Most controversial of all, the three Rs are about to become two. For most people, fluent reading and lucid writing will become far more important skills than arithmetic. Language studies, too, may become redundant as instantaneous translation removes the need for fluency in languages other than English.

Personal service will be an important growth area. People generally prefer to be served by a human being, at least for high-value purchases, for personal care such as beauty treatments or hairdressing, and for sorting out problems. Mass-market offerings will be largely automated, but niche players will be able to charge a premium for personal service by a human being. Just as at present good sales skills command high salaries, so in the future, good social skills will command high salaries. Hand-crafted products may command higher prices than robot-produced ones, simply because they were lovingly produced by humans – especially if the sales offering also involves human service.

For the time-poor, high-skilled, high-waged elite, the support of others is already essential to enable them to function and is likely to become even more so in the future. They may rely on robots to clean their houses, do the gardening, walk the dog, manage their diaries and organise their childrens' birthday parties – but it seems likely that most will prefer to have some human support, if only because it is likely to be seen as higher value. We may see a return to Victorian days, with a large proportion of people once more 'in service', as it used to be called: European statistics already show an increase in low-skilled employment in private households.

It is women who have seized the initiative in the growing service industries, and it is probably fair to say that this has been encouraged by a common perception that women are better at the 'softer' skills than men. Whether this is innate or simply a matter of cultural stereotyping and educational norms is debateable, and it seems likely that as time goes on we will discover whether the majority of men really can adapt to a more service-oriented work ethic.

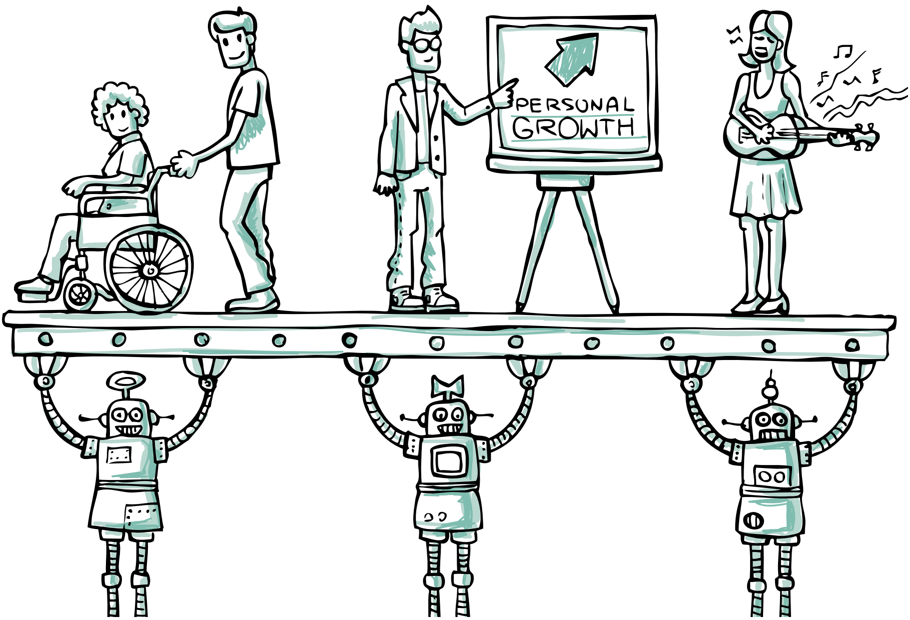
At present too many men associate 'work' with 'making stuff': it is these men who are most likely to suffer as 'making stuff' becomes the province of robots and they are unable or unwilling to adapt to work in service industries.



But there are already many men working in service industries. The counselling industry is dominated by women, but in the related world of psychotherapy there are a much greater number of men. Personal shoppers are almost all women, but a high proportion of personal trainers are men. Personal image consultancy is dominated by women, but motivational training is dominated by men such as Anthony Robbins. Massage is almost entirely women's work, but in physiotherapy, osteopathy, chiropractic and Alexander Technique the balance is much more even. And increasingly, we pay others – still more women than men, though that is gradually changing – to care for those who can't care for themselves. In so doing we recognise the value to society of both the carers and those cared for.

Those who bewail the loss of the UK's industrial base, sniff at service industries and think that only 'making stuff' is proper work, are living in the past. The fact is that the UK is already a service-oriented economy. Over 75 per cent of UK GDP comes from services, and it runs a substantial trade surplus in services. The UK's strength in services positions the UK better for the future than economies in which jobs are more dependent on manufacturing. The future of work lies in social activity and caring for people, not 'making stuff' that we can produce for nearly nothing with little human involvement.

We have a choice. We can continue with the ways of the past, competing with each other and with robots, valuing producing over caring, and insisting that everyone must produce in order to live. Or we can embrace the opportunities that technological changes bring, cooperating with robots and with each other to achieve more than we could individually, sharing work and its rewards equitably so that everyone has the means to live, and learning to recognise and reward activities that are currently unpaid and skills that are currently unrecognised. I hope we choose the path of change.



PART 2.

TECHNOLOGICAL POSSIBILITIES

THE NEXT BIG THING(S) IN ROBOTICS

ALAN WINFIELD

The second wave of robotics has started. The first wave got going around 50 years ago with industrial automation – exemplified by assembly line robots – the kind that build cars and washing machines. A hugely successful technology, first generation robots have revolutionised industrial and warehouse automation. And, more recently, first wave robotics technology has brought automation to the science lab – think of gene sequencing. There are few areas of human endeavour not touched by first wave robotics. From undersea exploration to robot milking machines, from robot surgery to space exploration, first generation robots are hugely sophisticated machines.

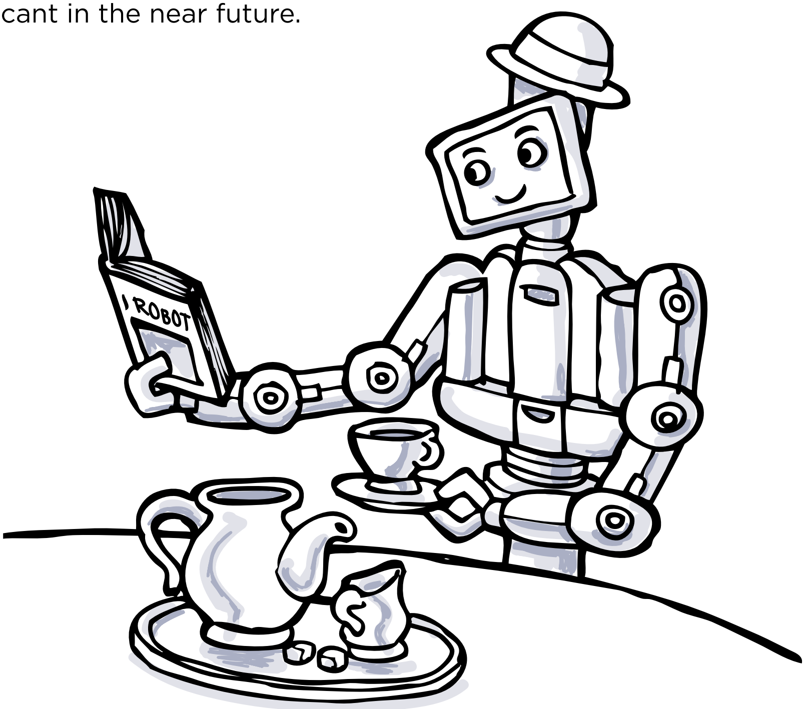
But something even more exciting is happening. Now underway, the second wave represents a kind of Cambrian Explosion in robotics: an astonishing and bewildering exploration of new forms, functions and materials. This explosion of diversity means that it's impossible to characterise the new wave as one kind of robot. Many are bio–inspired; together these comprise an extraordinary artificial zoo. Any prediction about which of these robot forms will successfully evolve to become mainstream is more or less impossible.

One thing we can be sure of is that second wave robots will be working with people, up close and personal. This contrasts with their first wave ancestors that, by and large, are dangerous for humans. In the vanguard of this second wave are workplace assistant robots like Baxter. This robot doesn't need to be behind a safety cage. Sharing a human workspace, Baxter acts as helper and co–worker.

Second wave robots will be networked (no surprise there), made of very different kinds of stuff (I'll have more to say about this later), and smarter – although not as smart as some would have you believe.

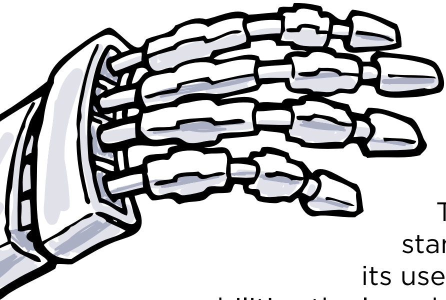
They will also be ethical. The way we think about robots will be different. As a society we will need to decide what robots should not do; a good example of how this is already happening is the current debate over autonomous robot weapons. We will expect our robots to understand us better, and to behave ethically – even if that means a robot occasionally does not do what we ask of it.

Having set out the landscape I will now attempt the very thing I claimed impossible: prediction. So, with a health warning, here are a few areas that I suspect will be very significant in the near future.



WEARABLE ROBOTS

Wearable robotics is one of the most exciting current developments in robotics – and one that could move from lab to real–world application within the next five to ten years. Wearable robots are not new – they've been around for a while in the guise of exo–skeletons, often intended for military applications. However, a new generation of wearable robots is beginning to exploit new materials and better human–robot interfaces. These wearables will, I think, bring huge benefits for the disabled, elderly or those recovering from orthopaedic surgery.



Wheelchair users, for example, experience all kinds of access problems, as well as the disadvantage of not being eye-to-eye with other adults. Imagine instead a simple wearable strap-on leg-chair. Light and self-powered, the leg-chair (the Right Trousers?) senses when its user wants to stand up and, well, stands up. Learning from its user while continuously adapting to their capabilities the leg-chair senses when they want to stand, walk, run for the bus, do cartwheels (well, why not..?), or any of the things most of us take for granted. Then makes it so, safely and intuitively.

An example wearable robot from the Bristol Robotics Lab is the hand exo-skeleton, designed as a rehabilitation aid for people who have lost hand function because of a stroke. Made from 3D printed plastic parts, the exo-hand senses the finger movements of its wearer and very gently adds a little extra power to those movements, thus reinforcing the user's efforts and – over time – helps to restore lost hand function. This is just a one-off prototype to prove the principle but it provides a wonderful illustration of the potential of wearable robotics.

IMMERSIVE TELEOPERATED ROBOTS

Teleoperated robots are the unloved poor relations of intelligent autonomous robots. Neither intelligent nor autonomous, they are nevertheless successful and important first wave robots; think of remotely operated vehicles (ROVs) engaged in undersea exploration or oil-well repair and maintenance. Think also of off-world exploration: the Mars rovers are hugely successful – the rock stars of teleoperated robots.

I think teleoperated robots need to be brought in from the cold and reinvented for the second wave. Anyone who has teleoperated a robot in real-world applications knows it is headache-inducingly frustrating; peering at a screen (or even worse, at three) with low-resolution images and viewpoints that make making sense of where the robot is and what it should be doing is next to impossible. It's no surprise that skilled robot teleoperators are hard to find. Immersive human-robot interfaces will, I think, change all of this.

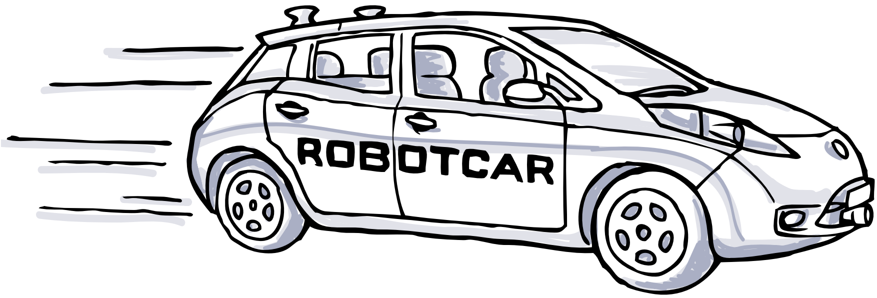
Roboticists are good at appropriating technologies or devices developed for other applications and putting them to good use in robotics: look at WiFi, mobile phone cameras and the Kinnect. There are encouraging signs that immersive Virtual Reality (VR) is about to become a practical, workable proposition. Of course VR's big market is video games – but VR could revolutionise teleoperated robotics.

Imagine a teleoperated robot with a pan–tilt camera linked to the remote operator's VR headset, so that every time she moves her head to look in a new direction the robot's camera moves in sync; so she sees and hears what the robot sees and hears in immersive high–definition stereo. Of course the reality experienced by the robot's operator is real, not virtual, but the head mounted VR technology is the key to making it work. Add haptic gloves for control and the robot's operator has an intuitive and immersive interface with the robot.

DRIVERLESS CARS

Nearly–driverless cars are already a reality. Buy a certain top of the range Mercedes and it will be equipped with automatic lane control, called Intelligent Drive. It's like cruise control except that the car can also keep its position in the centre of the lane – on the autobahn – while also checking and adjusting its speed to maintain a safe distance behind the vehicle in front. While in intelligent drive mode this car is doing what autonomous mobile robots do: using its sensors to continuously monitor its immediate environment, analysing all the sensory data, then using its control system to decide how to adjust the car's steering, accelerator and braking systems according to a set of rules for safe motorway driving.

Sounds wonderful (if you can afford a top of the range Merc)? Well no. The problem is that while the car is in intelligent drive mode you can't read a book, or watch TV, or check your emails. That would illegal. This is because even though the car is probably better and safer than you on the motorway, you are still in charge. In fact the car will warn you if you take your hands off the steering wheel for longer than ten seconds. The law demands that you watch the road and continuously monitor the situation so that you can take over in a second. If there's an accident it is you who is responsible, not the car.



This illustrates the current problem with driverless cars. The technology exists and is pretty well road tested. Contrary to popular opinion Google didn't invent the driverless car. Europe has a long history of driverless car research – nearly 20 years ago a research group at University BW Munich demonstrated a Mercedes 500 driving from Munich to Denmark on regular roads, at up to 180 km/h, with surprisingly little manual driver intervention – about 5 per cent. The 2007 DARPA Urban Challenge showed driverless cars coping pretty well with cluttered urban environments, complete with other cars behaving unexpectedly, bicycles, street furniture and so on.

So the technology exists and, in a limited form, you can buy it now. The problem of driverless cars has shifted from one of engineering and technology, to one of legislation and insurance – as well as the human factors of how we all adjust and get used to roads on which some cars (initially most of them) are manually driven, and others driverless (with occupants who are really not paying attention to the road). There is no significant technical reason why, in five to ten years, an elderly person without a driving licence couldn't have a small car that takes her from home to the local shop to pick up groceries, then on to a friend's house for tea, perfectly safely and automatically.

SOFT ROBOTICS

Soft robotics, as the name implies, is concerned with making robots soft and compliant. It's a new discipline that already has its own journal, but not yet a Wikipedia page. Soft robots would be soft on the inside as well as the outside – so even the fur covered Paro robot is not a soft robot. Soft robotics research is about developing new soft, smart materials for both actuation and sensing, ideally within the same material. Soft robots have the huge advantage over conventional stiff metal and plastic robots, of being light and, well, soft. For robots designed to interact with humans that's a huge advantage because it makes the robot intrinsically much safer.

Soft robotics research is still at the exploratory stage, so there are not yet preferred materials and approaches. In the Bristol Robotics lab we are exploring several avenues, one is electroactive polymers (EAPs) for artificial muscles; another is the bio–mimetic 3D printed flexible artificial whisker. A third approach makes use of shape memory alloys to actuate octopus–like limbs, as demonstrated in the EU OCTOPUS project. One of the most unlikely, but promising, approaches exploits fluid–solid phase changes in ground coffee to make a soft gripper: the Jaeger–Lipson coffee balloon gripper.

Unlike the three application domains I have outlined above – wearable robotics, immersive teleoperated robots and driverless cars – soft robotics is a new underpinning technology. A huge number of types of robots will benefit from soft, smart materials – including the wearable robots described above. One of the reasons we need soft, light materials is that robots designed to work closely with humans need, above all, to be safe. A way to make then intrinsically safe is by making the robot soft, light and compliant – so even if the robot were to fall on you it would do no more damage than if a young child fell on you. One effect of soft robotics is that many future robots will look very different: less mechanical and more organic. Most robots in research labs are already 3D printed rather than machined from metal; next generation 3D printers will enable us to print soft robots.

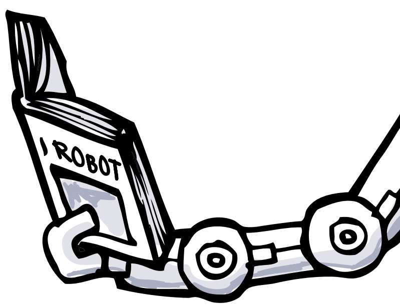
WHAT'S NOT COMING SOON

Some will be surprised that I have not written about robot intelligence here, apart from suggesting that the second wave of robots will be smarter than the first. My omission is deliberate, and there are two reasons.

The first is that robot intelligence still has a very long way to go before the science fiction dream of android robots with human–like AI – like Data from *Star Trek,* or *Bicentennial Man* – become a reality. Some are predicting that human–equivalent AI is only a few decades away, and if you believe the hype, once that point is reached all bets are off. Some believe this event – which they call the singularity – will usher in a new utopia in which super–intelligent machines will solve the world's problems. Others are equally convinced that super–intelligent AI poses an existential risk to humanity; AI, they declare portentously, will be humanity's final invention. The utopians and dystopians are equally wrong, in my view, both about how long it will take to build machines as smart as humans, and the question of what will happen after that.

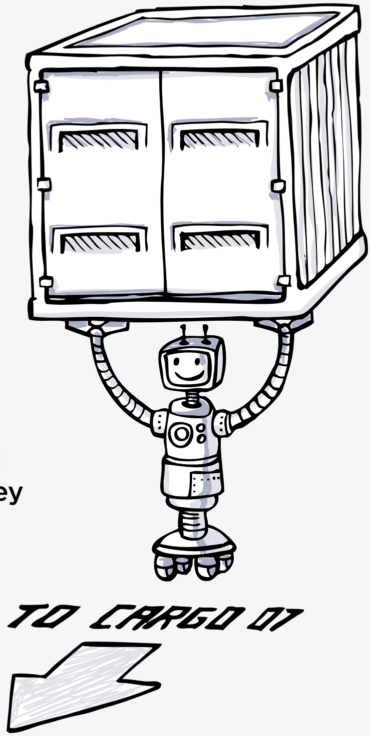
The reason making really intelligent machines will take a long time is because it is a very hard problem. We don't even understand what intelligence is – only that it is not one thing that humans or animals have more or less of. Nor do we yet understand how intelligence works in animals and humans; to paraphrase a famous SF short story, we don't know how meat can think. But the good news, and this is my second reason for not promoting super–intelligent robots in this article, is that there is truly massive potential for really interesting and hugely useful smarter – but still not very smart – robots. It is a myth that robotics is somehow waiting for a breakthrough in AI before its true potential can be realised.

My predicted things that will be really big in robotics don't need to be super intelligent. Wearable robots will need advanced adaptive (and very safe and reliable) control systems, as well as advanced neural–electronics interfaces, and these are coming. But ultimately it's the human wearing the robot who is in charge. The same is true for teleoperated robots: again, greater low–level intelligence is needed, so that the robot can operate autonomously some of the time but ask for help when it can't figure out what to do next (which we call dynamic autonomy). But the high–level intelligence remains with the human operator and – with advanced immersive interfaces as I have suggested – human and robot work together seamlessly. The most autonomous of the next big things in robotics is the driverless car, but again the car doesn't need to be very smart. You don't need to debate philosophy with your car – just trust it to take you safely from A to B.



AUTOMATIC FOR THE PEOPLE

NICK HAWES



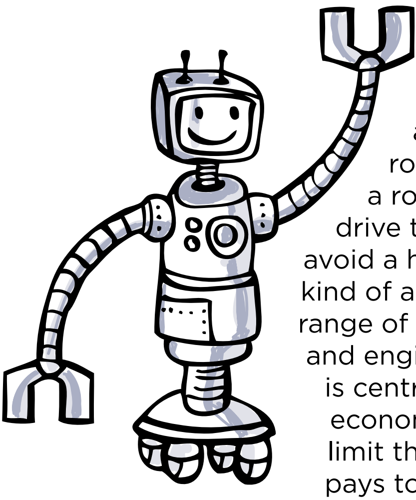
A robot is a machine which automates a physical task. By identifying tasks which could be automatically performed by a machine, many traditional manufacturing industries have been able to use robots to improve the performance of their production lines. Once a task can be done by a robot you are able to rely on that task being done to a predictable level of quality for as long as it's required. Industrial robots – the kinds of robots typically used in manufacturing – are built with this kind of predictability in mind: they are designed to repeat a fixed series of movements with sub-millimetre precision, enabling them to manipulate complex assembly parts in exactly the right way.

This level of precision and predictability is only made possible by placing industrial robots in highly regimented environments: environments where every grommet and widget lies in a known position and the movements of robots, conveyor belts and other devices are tightly synchronised. By knowing the position of everything in the environment, robot engineers can program the movements of industrial robots such that they can act out the correct behaviour time and again, without having to worry about checking whether anything in the world has changed.

BEYOND THE FACTORY FLOOR

Whilst this level of engineering and organisation is impressive, its use is strictly limited to the kinds of applications where such extreme levels of control can be put into place. And whilst the first wave of robots (industrial robots) could be confined to controlled environments, the future robot economy is predicted to be largely driven by service robots, robots which work for humans or with humans outside of the world of industrial automation. The application areas targeted by service robot developers include care, security, logistics, cleaning, and many other domains where robots would be required to work in the ever-changing worlds occupied by humans going about their day-to-day routines. It will be impossible, or at least extremely impractical, to exercise industrial levels of control in these environments. Therefore, if we want robots to work in these applications, we must apply a different kind of technology.

Industrial robots exploit controlled environments to blindly repeat fixed actions, ignorant of their consequences. Contrary to this, service robots must be aware of their environment (and more), and use this awareness to decide how to perform their actions.



In artificial intelligence (AI) and robotics, we refer to a system which can control its own future actions in this way as autonomous. Although autonomy in near-future service robots may be limited to just the way a robot is able choose its own route to drive through a building, or when to stop to avoid a human walking in its path, creating any kind of autonomous robot poses a significant range of challenges. As the ability for scientists and engineers to overcome these challenges is central to the development of a new robot economy, and the nature of possible solutions limit the abilities future robots will have, it pays to investigate the main elements of an autonomous system further.

SENSE, PLAN, ACT

To understand what is required to build an autonomous robot, imagine you've been asked to develop a wheeled robot that can cross a road. The industrial robotics approach would be to ensure there are times when no cars, or other dangers or obstacles, are present on the road (by installing a level crossing for example).

The challenge of building an autonomous robot that is capable of crossing a road can be broken down into three parts. First, the robot must be physically able to cross the road. In this case we will assume that our robot can drive from kerb to kerb, controlling its speed as it goes, and also monitoring its position on the road (an ability known in robotics as localisation). In many ways this is the easiest part of the problem as it relies mostly on traditional engineering and robotics technology. The harder parts must come before the driving starts. In order for the robot to cross safely, it must decide when it should start driving. This decision should be based on whether the robot thinks it is safe to do drive across the road or not, considering both its own safety and that of other road users. Crossing the road safely means leaving a suitable gap between the crosser and the traffic on the road. Therefore the final part of this challenge is to get the robot to sense where the traffic is in order to inform the decision about when to cross.

Before exploring the difficulties inherent in this problem in more detail, let's first extract the key parts of this problem. First the robot must sense the traffic and its surroundings (e.g. its location on the road), next it must decide when or whether to cross, then it must act based on this decision (the actual crossing of the road). This sense–decide–act cycle is commonly used to encapsulate the capabilities any autonomous system must possess (where 'decide' may sometimes be replaced with 'plan' or 'process'). However, the structure of this cycle should not be interpreted too literally. For example, a great many robotic tasks blur the boundaries between sensing, decision making and action (e.g. using feedback from a camera to get a robotic manipulator closer to an object for grasping), and the notion of a fixed cycle belies how real autonomous systems are typically implemented (with many different processes active in parallel and operating at different rates).

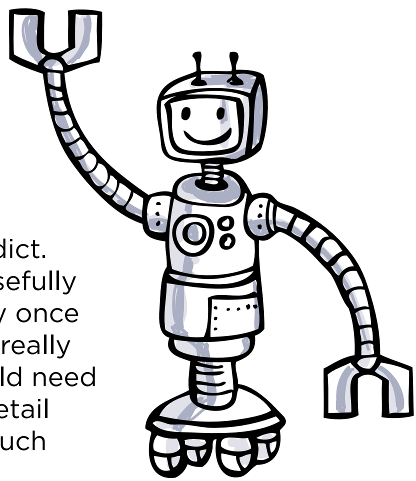
Returning to the road crossing robot, let us look into the component tasks in more detail. As the problem of driving across the road relies on relatively well–understood engineering, let us ignore it for now. Central to the rest of the system is the decision making problem of if and when the robot should leave the safety of the kerb and start crossing the road. Assuming this decision is made in a way that is similar to the way humans appear to do it, then the robot must examine the locations and speeds of the approaching traffic and determine if it can move from one side of the road to the other in a gap between vehicles. This is the kind of problem that calculus, and computers excel at, so assuming that the robot has all the information it needs (and we shall see later on that this is a big assumption), it should be able to correctly determine when to start driving across the road.

In order to populate the memory of the robot with the information it needs to perform these calculations, we must provide some method which allows the robot to sense (or more accurately, perceive) the position and velocity of any vehicle which could possibly reach the robot during crossing. Robots use a variety of sensors, but most measure the distance between the robot and the contents of its environment using either reflected light (e.g. laser) or sound (e.g. sonar). The main exception to this is the use of cameras to obtain images of the world around the robot. The sensing of distance values, or light frequencies and intensities, is the easiest part of this process. The harder part is to interpret these measurements in order to perceive what is implied by these measurements. In our example, this translates to enabling the robot to use a rapidly obtained series of 2D or 3D measurements to determine the locations of all the vehicles around it. There are many cues a robot could use (shape, size, presence on the road, motion, colour etc.), but few would reliably recognise all the possible vehicles our robot may encounter. More critically, all of these sensors suffer from occlusion, that is that if something gets between the robot and the target it is trying to sense, then that target effectively disappears (just like when someone steps in front of you when you're trying to take a photo of something important). This means that many of important features of the road may not be visible to the robot at any given instance of time. For example, what appears to be one car may actually be two, or the presence of a slow moving lorry may mask the approach of a fast moving motorbike.

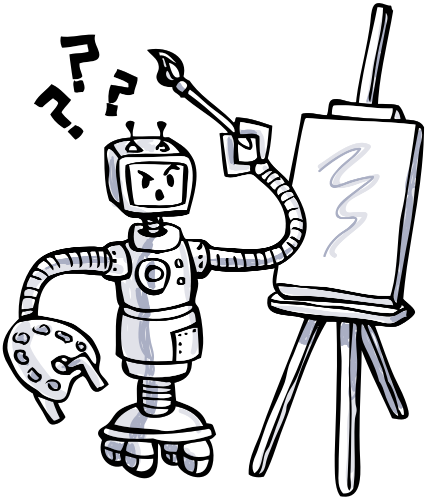
CERTAINLY UNCERTAIN

In robotics and AI we would say that these perceptual limitations mean that the robot is reasoning under incomplete information, i.e. some important information is missing from its decision–making problem. Problems with incomplete information in robotics are almost universally recast as problems where reasoning occurs under uncertainty, where the robot represents, for example, the probability that its laser reading contains one car, two cars, or one lorry and a motorbike (e.g. with probabilities of 0.6, 0.3 and 0.1 respectively). This makes the decision-making task considerably harder, as the robot must consider all of these different possibilities, and the likelihood of them occurring, when making its crossing decision. It is due to reasons like this that many researchers consider perception to be the main problem holding back to development of useful autonomous service robots. But it is also the case that large advances in probabilistic reasoning techniques in recent years have enabled commensurate progress in robotics.

Perceptual difficulties are not the only source of uncertainty in the decision-making task for crossing the road. The robot must predict the future locations of the vehicles it has perceived, in order to work out in advance of the vehicles being in the position they will occupy when it will start crossing, whether it can cross safely or not. To do this it must have some kind of predictive model of vehicle behaviour. This model could be simple (e.g. predicting that all vehicles travel at the speed they were last observed at) or could contain whatever complexity the robot designer deems fit (e.g. modelling the behaviour of drivers when they spot our robot waiting to cross the road). Regardless of its contents, the success of our road-crossing robot hinges on how well its models correctly predict the future behaviour of vehicles. If they work well, then the robot can safely use them to determine when to cross. If they predict badly, then either the robot will waste time frozen on a kerb, or it will risk being reduced to a pile of nuts and bolts making a crossing which it predicts should be safe, but is not in reality.



Hopefully this conveys the problem of developing an autonomous robot to operate in a world populated by other entities – also autonomous – which it cannot fully perceive or predict. The road-crossing problem is purposefully simple, but it gives rise to complexity once the details are examined. In order to really build a road-crossing robot you would need to explore the task in even greater detail (for example, addressing questions such



as how long should the robot think before deciding, how can you add the highway code to the robot's models, how the sound of approaching cars can augment their appearance) and consider important variations of the problem (e.g. how do different weather conditions influence things, or what if the robot had an urgent need to cross the road – e.g. to put out a fire – that may cause it to behave in a riskier manner). If you'd like to stretch yourself further, why not try to imagine how you'd build a robot that could a) learn to cross the road better (faster, more safely etc.), b) teach (human) children how to cross the road, or c) design roads such that they could be safely crossed by other robots.

ROBOTS IN THE WILD

Two challenges: enable these parts to solve the problems that face them in the world (somewhat traditional AI) and also combine them into a single working system. This is where the new wave of robotic and AI is coming in.

Now we have a rough idea of challenges that confront the creators of the next revolution in robotics, we can ask where progress needs to be made in order for us to really see robots in our places of work. In general, efforts need to be made in two areas: components and systems. The components are the parts of a robot's software or hardware that contribute some element of functionality to the overall system. From our example above, this could be a software component that detects cars in laser scans, estimates the future positions of cars given a prior car detection, or the decision–making component that calculates the probability of making a successful crossing at a point in time in the future. Researchers in AI and robotics are working on many problems similar to these, and will inevitably make much progress in the coming years. However, these fields are notoriously reductionist. This is understandable since the problem of creating an (intelligent) autonomous system to perform even a simple task in the real world can be alarmingly complex. However, this reductionist approach means that most bits of science that would naturally contribute components to autonomous robots make simplifying assumptions which are not true when placed in a robot in the real world. For example, the field of AI planning which studies which actions an autonomous system should take to achieve a goal typically ignores the fact that the world can change independently of the system (including as it plans), and the field of computer vision (which is naturally placed to enable robots to understand the world through cameras) predominantly works in the two dimensions of a single imagine, ignoring that robots will need to care about both what an object is and where it is. In robotics, the technologies for creating maps which a robot can then use to navigate with have long assumed that they are creating maps of unchanging worlds, despite most environments rarely remaining unchanged (at some level) from day to day.

To overcome such assumptions, it is therefore crucial that more time and effort is spent creating complete autonomous robot systems, rather than building ever more elaborate (but potentially flawed) components. This will naturally come about as more industries look for service robot solutions and find the existing component technologies lacking. It is also happening more in academia thanks to large–scale robotics science funding from the European Commission who are placing an increasingly significant emphasis on complete (integrated) robot systems operating in real world (instead of laboratory) environments.

WHERE NEXT

The challenges inherent in creating autonomous robots will naturally shape their development, uptake and use. You can already buy an autonomous robot to cut your lawn and a different one to sweep your floor, but you can't buy one that does both. This is because these tasks require both different robot bodies and different robot brains, and we are a very long way away from creating a single robot which can do a range of things with the same hardware and software setup. The service robot industry will grow along the same lines as the domestic robot industry: special purpose systems capable of doing a single task autonomously.

Humanoid robots present an alternative viewpoint from this, as their form is such that they could physically perform a range of tasks similar to that of a human, but they still require control software to enable each task. In some ways, this potentially makes a humanoid robot a sensible investment, providing such software exists. This is the exact conundrum faced by potential purchasers of the Rethink Robotics Baxter robot, although this is supposed to be alleviated by programming by demonstration.

The tasks near–future service robots will do will be shaped by a mixture of their capabilities and the economics of their use. In terms of capabilities, variation is the enemy of autonomy. The less variable an environment or task is, the less effort it is (relatively speaking) to create an autonomous system to successfully perform in that environment or to reliably, repeatedly complete that task. Consider the difference between creating a road–crossing robot that only needs to cross cul–de–sacs on housing estates, and one that must cross any road a human might have need to cross (town high streets, winding country lanes etc.). Similarly, imagine a robot which must clean the corridors of a hospital. One which must only clean predominantly empty corridors (say at night) will be easier to create than one that must also operate during peak hours cleaning up spillages on demand.

In terms of economics (but still within the constraints of capabilities), the tasks near–future service robots will perform must be such that the benefit of performing them repeatedly and predictably (as robotic automation affords) exceeds the cost of the investment in the robotic technology. Therefore applications where the first autonomous service robots will appear are those where the scale of the task provides this value (e.g. cleaning the floors in a large chain of fast food restaurants; security patrols in government or large corporate offices; warehouse logistics in large distribution chains) or it comes more directly from the value of the task itself (as in high–value manufacturing).

In conclusion, when heading into our robot–supported future, it is important to be aware of the importance of autonomy–enabling software in allowing robots to work in human environments, even if the tasks they perform are limited at first. It will also be important for the public at large to be aware of the challenges in generating reliable autonomous behaviour in robots, as it is these challenges, more than anything, that will shape their performance and their impact on our society.

PART 3.

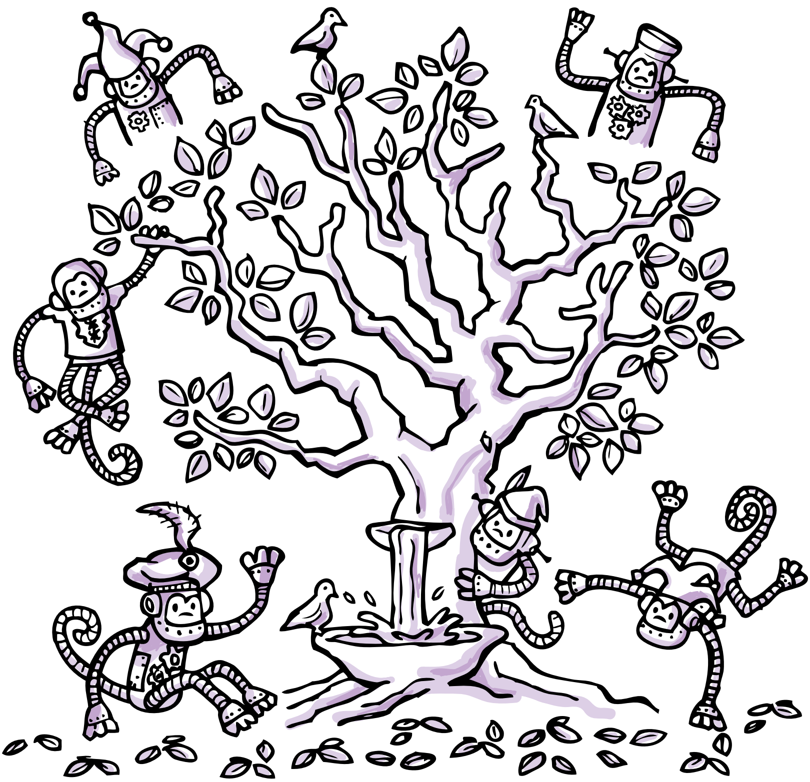
ROBOTS OF THE PAST AND OF THE FUTURE

THINKING WITH ROBOTS: THE SECRET HISTORY OF EARLY AUTOMATA

E. R. TRUITT

Robots permeate our modern lives. Robots help us perform surgery, build cars, explore space, and clean house. Non-fiction and fiction authors sketch out our futures with robots, from David Levy's *Love and Sex with Robots* (Harper, 2008) to Daniel H. Wilson's *Robopocalypse* (Doubleday, 2011). Films and television explore our complicated relationships with artificial people: as exemplars of humanity in *Battlestar Galactica* and *Blade Runner,* as substitutes for interpersonal connection in *Robot and Frank*, and as comparands to the faceless workers of global capitalism in *Metropolis.* We use robots to undertake different kinds of work: to replace or augment human labour and to imagine new forms of human behavior, to evoke socially appropriate emotional responses, and to demonstrate important cultural boundaries. Yet robots — self-moving, artificial objects — have been contemporary for a very long time. These objects, sometimes called automata, appear as silent metal guardians, talking statues, and lifelike birds in narrative texts and courtly pageantry throughout the ancient, medieval, and early modern periods. In these eras automata perform utilitarian functions, just as they do now, but their more abiding purpose was to model or enforce social norms of behavior, political power, or personal relationships.

From their first appearance in ancient culture, robots have been imagined and built to serve humanity. Some of the earliest examples come from *The Iliad.* According to Homer, Haphaestus forged twenty servants, mounted on wheels, to serve the gods on Mount Olympus. He also made two golden handmaidens, endowed with speech, thought, and action; these assisted him in his workshop. Artificial handmaidens appear later in tenth and eleventh-century Sanskrit literature: they serve wine and spray perfumed water from their eyes, nipples, and fingernails. There is some evidence to suggest that the authors of these Sanskrit romances may have drawn their descriptions of mechanical female attendants from actual courtly objects. Certainly the technical knowledge needed to make these objects was already available in nearby parts of the world. Al–Jazari, an engineer and courtier to the Urtuqid rulers of Diyar–Bekr in the early thirteenth century, wrote a treatise on automaton making that included a detailed design for a female wine servant. Al–Jazari based his *Book of*



Ingenious Mechanical Contrivances on the ninth–century *Book of Mechanical Devices* by the Banu Musa, a family of scholars and engineers based in Baghdad. Al–Jazari's design was of a female figure, over a meter high, mounted on an inclined plane and under a domed reservoir. The reservoir would be filled with wine, which trickled at a steady rate from the reservoir into a basin below. Once the wine in the basin reached a certain level, the weight would cause the basin to tip and pour the wine into the wineglass in the girl's hand. Once the wineglass was full, the additional weight caused the figure to roll down the inclined plane toward the drinker, with the wineglass offered in her outstretched hand. In her other hand, she held an embroidered cloth, which she offered to the drinker to wipe his mouth, once he lifted the wineglass. Just over a century later, in the mid-fourteenth century, European artisans began to design elaborate musical fountains that dispensed wine or scented water, and these were often incorporated into royal and noble feasts as part of the pageantry of aristocratic largesse.

Scientists also designed and created artificial objects to perform calculations, including calculations about the passage of time. The Antikythera Mechanism (ca. 80 BCE), likely the only surviving automaton from the ancient period, was a programmable machine about the size of a laptop. It contained numerous precise gears that modeled and indicated celestial movements, and may have been used to predict astronomical events, such as eclipses. In areas such as Syria and Persia, where the Greek intellectual tradition continued uninterrupted, astronomical calculation and timekeeping remained important. After the Arabic conquests of the seventh and eighth centuries brought these areas under Muslim political control, the functions of timekeeping and calculation were often combined with automata. In the early ninth century, the ‘Abbasid caliph Harun al-Rashid sent from Baghdad to Charlemagne at Aachen a water clock (clepsydra) with multiple moving figures. The clock was made of brass, and sounded the hours

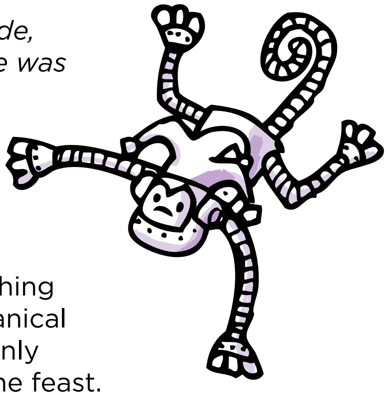
> *“...with the right number of little bronze balls, which would fall into a basin and make it ring. (This clock) also had the same number of horsemen, and they would, through twelve windows, come forth at the end of the hours. With the force of their exit they would close the proper number of windows, which had before been open.”*

The clepsydra with the metal horsemen is only one example of a time-telling device with moving figures. A few centuries later, in the mid-twelfth century, the emir of Damascus, Nur al-Din ibn Zangi (ca. 1118-1174), commissioned a massive clepsydra for the eastern entrance to the Great Mosque of Damascus. A larger version of Harun al-Rashid's gift, the clock face contained twelve doors with openings at either end; through each of these a bird appeared above a basin. The birds marked the hours by dropping pellets into the vessel below. Above the doors a series of discs represented the solar and lunar cycles. Many of these features also appear in al-Jazari's slightly later design for the 'Castle Clock'. Over eleven feet high, the clock was a complicated astronomical calculator and time-keeping machine. It displayed the positions of the stars, marked the journey the sun across the ecliptic, and demonstrated the phases of the moon. The clock signaled the hours of the day via twelve apertures with small human figures inside them, and mechanical falcons that dropped balls into glass bowls to sound the hours. The clock also had several musical figures attached to it: two drummers, two trumpeters, and a cymbalist. A few centuries later, in Latin Christendom, the invention of the mechanical escapement, a more accurate way of marking the passage of time, led to the proliferation of monumental astronomical clocks—huge machines that were powered by massive falling weight drives, and often installed in wealthy churches. These clocks performed complicated astronomical calculations and represented the orderly movements of the heavens. The falling weight drives provided enough power for multiple trains of automata: roosters to crow every hour, mechanical bell-ringers, and religious figures, such as the Virgin Mary or Jesus, to embody the concurrent timeline of human salvation.

Objects like Harun al-Rashid's clepsydra and al-Jazari's handmaiden did more than tell time or pour wine. They demonstrated the power and wealth of the prince or sovereign, and they were intended to evoke wonder, amazement, desire, and also some fear. As early as the start of the Common Era, the rulers of Alexandria used large mechanical figures in public processions, festivals, and other elements of ritual and statecraft. Later, in the ninth century, just a few decades after Harun al-Rashid sent his gift to Charlemagne, the 'Abbasid caliph al-Mam'un installed in one of his palaces an artificial tree, with gold and silver branches, and ornamented with mechanical musical birds. In the early tenth century, a Byzantine diplomat to the 'Abbasid court described the 'Palace of the Tree', as it was called, and marveled at the mimetic exactitude and rich beauty of the artificial birds that sang on its branches. This diplomat, Romanos Lekapenos, went on to become the Byzantine emperor several years later. And just a few decades after Lekapenos' visit to Baghdad, a Latin diplomat in the mid-tenth century, Liudprand of Cremona, described the elaborate automata and apparatus of majesty at the court of the Byzantine Emperor in Magnaura Palace in Constantinople. The emperor's magnificent throne and the automata that surrounded it recall the automata of 'Abbasid pageantry, with a few additions. According to Liudprand, the emperor sat on the Throne of Solomon next to a bronze and gilt tree, *"whose branches were filled with birds, also made of gilded bronze, which uttered different cries, each according to its varying species."* Massive mechanical lions flanked the throne, and at his approach the lions thrashed their tails, opened their mouths, and roared. And when Liudprand glanced up after his prostrations before the throne, he discovered that it had risen up to the ceiling and that the emperor, seated on the throne, had changed his clothing. The pageantry and spectacle of the Byzantine court was intended to convey the importance of the emperor as the divinely anointed ruler and to intimidate his visitors. Liudprand, the wily courtier, assures his reader, *"I was neither terrified nor surprised, for I had previously made enquiry about all these things from people who were well–acquainted with them."*

Mechanical objects were not incorporated into courtly spectacle in western Europe until the fourteenth century. The Valois kings of France, the dukes of Burgundy, and the crowned heads of England and Spain all used mechanical objects as part of their pageantry, and for different purposes. Some of the items, like lavish musical wine fountains, recall their earlier Greek and Arabic counterparts. Others, like the mechanical golden angel that crowned Richard II of England during his coronation procession through London in 1377, operated on multiple symbolic levels. The angel, built by the Worshipful Company of London Goldsmiths, lowered the crown onto Richard's head during a stop on his progress through Chepe, the center of the goldsmiths' trade. The angel demonstrated to the onlookers that Richard's right to rule as king came directly from God. Yet it also embodied the economic power of the goldsmiths in London, without whose support Richard could not hope to rule. Still other kinds of objects were intended for education and entertainment at royal banquets.

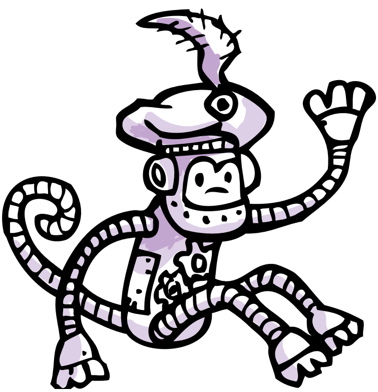
At a feast to celebrate the coronation of the wife of Ferdinand I of Aragon in 1414, theatrical machinery was used as part of the entertainment. A device called a cloud, which worked by concealed mechanisms, descended from the ceiling to amaze the guests. During the feast, the figure of Death appeared in the cloud and captured a jester named Borra and hanged him. A witness wrote,



"You would not believe the racket Borra made, weeping and expressing his terror, and as he was pulled up he urinated into his underclothes, and the urine fell on the heads of those below. He was quite convinced he was being carried off to Hell. The King marveled at this and was greatly amused, as were all the others." Poor Borra. His unfeigned terror highlighted the astonishing and sometimes frightening aspect of mechanical marvels, yet his discomfort and ignorance only added to the amusement of the guests at the feast.

The most famous example of machinery deployed in the service of spectacle and Schadenfreude is found at the Burgundian castle of Hesdin in the fifteenth century. Since the early fourteenth century, the estate had contained an elaborate pleasure garden with an artificial lake, a pavilion with a mechanically gesticulating king, six artificial monkeys that made gestures, and an elaborate fountain that looked like a tree with gilded, musical birds on its branches. The 'engines of amusement,' as they were called in the estate's record books, fell into disrepair during the Hundred Years' War. They were sumptuously renovated, refurbished, and updated in the 1430s by Philip 'The Good' III, Duke of Burgundy. Because the duchy comprised several distinct geographic territories and lacked a common language, Philip employed spectacle and an imposing court as a way to bind together the disparate territories under his rule and create a sense of shared aristocratic culture. He kept a sumptuous and formal court, which was noted for its extravagance, and he employed numerous artists and artisans—jewelers, painters, sculptors, and carpenters—to create the ostentatious and inventive feasts and spectacles that marked his rule. Once he ascended to the dukedom, Philip spent well over a thousand pounds—an incredible fortune in today's economy—re-plumbing the fountains, re-gilding the birds, and re-pelting the monkeys. He also installed an entirely new 'Gallery of Delights': a sort of fun-house in which unwary courtiers would be pummeled, mocked, sprayed with dirt and flour, and soaked with water. Many of the objects in the Gallery were intended both to subvert courtly norms of etiquette and to uphold them. As part of the formality of his court, Philip usually dressed in all black—a product of the most expensive dyes—and required his courtiers to wear elaborate and richly coloured costumes, which highlighted his own understated clothing. Trick mirrors were set throughout the gallery, and the courtier's usual concern for appearance was counter–productive; the more care for attire and coiffure, the greater the upset to dignity. Adding insult to injury, some of the mirrors would also cover with flour the person standing before it.

The automata in the gallery and park at Hesdin underscored the formality of the ducal court by disrupting it in a controlled setting. For example, a mechanical figure told everyone that the duke commanded that they leave the gallery. Those who hurried to obey the duke's command were pushed off a bridge and beaten by other figures armed with sticks. Those who tried to choose self–preservation over the rules of precedence were sprayed with water. And all through the gallery, close to ground level, were concealed jets that, at the duke's command, would *"wet the ladies from below."* As with all marvels, reaction to the devices depended on perspective. If one, such as the duke or an experienced courtier, was in on the tricks, then the automata were not terrifying; they were, instead, amusing and entertaining. In this way the 'engines' at Hesdin are very similar to the Throne of Solomon encountered by Liudprand of Cremona on his embassy to Constantinople. The experiences of courtiers and guests at Hesdin or the Byzantine emperor's throne room became part of the performance for those who were more seasoned or knowing, just like Borra's terror at the feast of Ferdinand I of Aragon. The distress, pain, surprise, or terror of those in the gallery heightened the enjoyment of any onlookers, perhaps in part from Schadenfreude, and also because their distress underscored the gulf between knowledge and ignorance, between inclusion and exclusion.

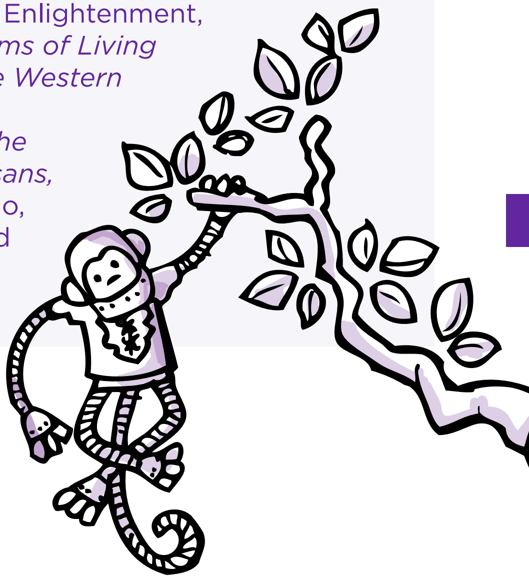


Even before the Duke of Burgundy and his forebears installed mechanical marvels at Hesdin, reports of wonderful devices from distant lands kindled the imagination of medieval European writers, chroniclers, and scholars. Mechanical animals, musical fountains, and pitiless metal guardians appear in medieval literature as early as the twelfth century. Some of these figures—copper knights or golden archers—guard palaces from intruders. Others display a more pointed kind of perception, intended to uphold social norms. In one example, found in a thirteenth–century French version of the story of Perceval, two artificial figures—a knight and a maiden—stand sentry outside the tent of a foreign ruler. The knight barred the entrance to all except the nobility, while the maiden signaled if a female visitor was a maiden no longer. In another example, this time from an Old French version of the Iliad, the Trojan nobility gather in the Alabaster Chamber, where they are entertained and subtly disciplined to enact perfect courtly behavior. Four beautiful golden automata—two young boys and two maidens—grace the hall. One of the maidens holds up a mirror so that the courtiers can make sure that their attire is correct, while the other one performs gymnastics and conjuring tricks. The second maiden's performance is so captivating that it prevents the spectators from leaving too early, thereby committing a breach of etiquette. One of the male figures plays music that acts as a cover for private conversations and also banishes vulgar or unkind thoughts. The fourth automaton monitors all of the behavior of the people in the Alabaster Chamber and conveys to them, by confidential hand gestures, the ways in which their behavior is unacceptable, and how to change it. The purpose of these figures was to enforce particular norms — of appearance, behavior, and thought — and to help courtiers fit in. These earlier, imaginary examples do some of the same cultural work of the later mechanical marvels at Hesdin and at the royal courts of fourteenth and fifteenth century Europe: they police the boundary between inside and outside, between what is permitted and what is not allowed.

Using robots to model and instruct people in correct behavior and attitude continued in the early modern period. In the sixteenth century, King Phillip II of Spain commissioned a mechanical monk that performed the proper sequence of steps, gestures, and prayers for Catholic devotion. The monk was intended to perform pious discipline and to instruct the penitent observer how to pray in order to give rise to an ecstatic, trance–like state of religious devotion. Slightly later, in the Enlightenment, fine technicians designed and built musical automata that not only played music perfectly, but also performed the proper intervals of breathing and gesture that would indicate the musician's emotional connection to the music. The goal was that the audience would learn the proper physical response; then this knowledge would correspondingly engender an emotional response and, more broadly, greater social unity over shared cultural values. These examples demonstrate that humans have been imagining, designing, building, and using machines to perform and reproduce the entire spectrum of human ability—manual labor, complex intellectual work, and emotional experience—for millennia. As with earlier eras, our contemporary robots can reveal an enormous amount about our current preoccupations, desires, and fears, as they raise questions about the role of complex technology in our lives, problematise the boundary between natural and artificial, and embody the ethical ramifications of knowledge.

NOTES FOR FURTHER READING:

The literature on pre-modern and early modern automata is more robust than the general interest in the topic would indicate. The examples from *The Iliad* can be found in Book 18. For a primer on ancient automata and the Antikythera Mechanism, see Susan Murphy, Heron of Alexandria's 'On Automaton-Making'*, History of Technology,* Vol. 17 (1995): 1–45; Tony Freeth, Alexander Jones, John M. Steele, and Yanis Bitsakis, 'Calendars with Olympiad display and eclipse prediction on the Antikythera Mechanism,' *Nature* 454 (31 July, 2008): 614–17; and Karin Tybjerg, 'Wonder-making and philosophical wonder in Hero of Alexandria,' in *Studies in History and Philosophy of Science* 34 (2003): 443–466. Automata are found in two medieval Sanskrit romances; see *Yasastilakacampu,* edited by P. Sivadatta and Kasinath Pandurang Parab (Bombay, 1901); *Srngaramanjarikatha,* edited and translated by K. M. Munshi (Bombay, 1959). On the importance of pleasure gardens in secular Indian culture, see Daud Ali, 'Gardens in Early Indian Court Life,' *Studies in History* 19 (2003): 221–52. The Frankish account of Harun al-Rashid's gift is in the *Chronicles of the Frankish Kings* (Hanover, 1895), ann. 807. Al-Jazari's treatise on automaton making, *The Book of Ingenious Mechanical Contrivances,* is available in English in Donald Hill's translation (Dordecht, 1974), and D. Fairchild Ruggles (Philadelphia, 2008) and Finbarr Barry Flood (Leiden, 2001) have written about the importance of automata and timekeeping devices in medieval Islamic culture. Liudprand of Cremona's account of his journey to Constantinople is available in English as *The Embassy to Constantinople and Other Writings,* translated by F. A. Wright and edited by John Julius Norwich (London, 1993). On automata and mechanical marvels in late medieval courtly culture, including the accounts of Richard II's coronation pageant and Ferdinand I's banquet, see Scott Lightsey, *Manmade Marvels in Medieval Literature and Culture* (New York, 2007). On medieval automata more generally, see E. R. Truitt, *Medieval Robots: Automata, 800–1450* (Philadelphia, forthcoming), and on the robots of the early modern period and Enlightenment, see Minsoo Kang, *Sublime Dreams of Living Machines: The Automaton in the Western Imagination* (Cambridge, 2011), Adelheid Voskuhl, *Androids in the Enlightenment: Mechanics, Artisans, and Cultures of the Self* (Chicago, 2013), and the work of artist and scholar Elizabeth King (www.elizabethkingstudio.com).



OUR WORK HERE IS DONE: ROBOT FUTURES IN FICTION

JON TURNEY

> *In ten years Rossum's Universal Robots will produce so much corn, so much cloth, so much everything, that things will be practically without price. There will be no poverty. All work will be done by living machines. Everybody will be free from worry and liberated from the degradation of labor. Everybody will live only to perfect himself.*
>
> **R.U.R. 1920**

> *A robot economy isn't just like our economy, but with robots substituted for humans. Things would soon change very fast.*
>
> **Robin Hanson**

What shall we think about robots? Our experience of them is of two kinds. Some people now research, operate, or work alongside real robots. There must be quite a few of them. Worldwide sales of industrial robots are well over 100,000 annually. But this actual experience of real machines is probably outweighed by the enormous number of robots in fiction.

These are, on the whole, quite different from the real ones. Science fiction, in books and magazines and then on film, has taken up the ancient myths of creating artificial beings and automata with inexhaustible enthusiasm. They have been worked and re-worked into a series of plots which have become clichés because of their enduring appeal.

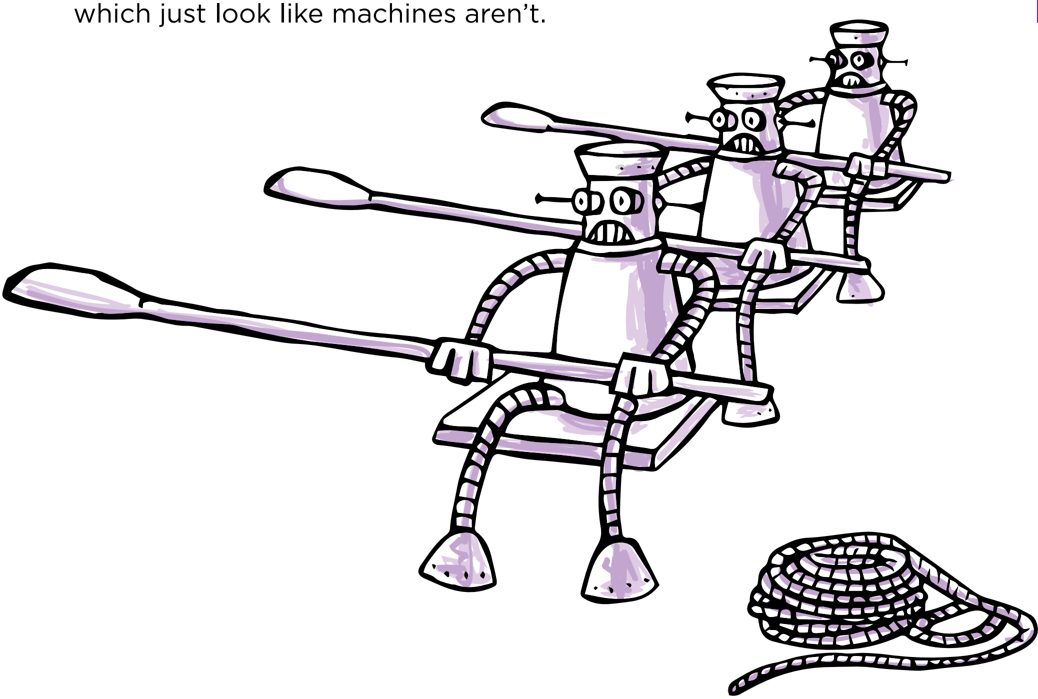
These normally involve robots which are more or less humanoid, and hence bear little resemblance to most of the ones technologists have made so far – excepting those which have been deliberately fashioned to look like science fictional robots as attention-grabbers or, in a few cases, to explore aspects of human-machine interaction. However, amid the universe of SF stories, there are still a few which can illuminate an important question posed by the advent of machines which can perform labour previously done by people: what shall we do when work is taken care of?

Work is not an aspect of life which science fiction often deals with convincingly or well – something it shares with literature outside the genre. The definitive *Encyclopedia of Science Fiction* has no entry under 'work'. But when work does go on in science fiction stories, some or all of it gets done by robots.

It is relatively rare for work as such to drive the story, though. It more often forms a backdrop to a plot driven by one of the robot themes we can all recognise. A few words about those help put some observations about work in context.

It is generally accepted that science fiction set in plausibly extrapolated futures is best read as commentary on the present. In the same way, it seems fair to say that science fiction about humanoid robots – or other artificial people – is about people. The themes here underpin the treatment of robots at work.

So science fiction took up the ancient question of whether humans can create artificial beings via robots and androids. The almost obsessive concern is how like a human such a creation can be – and hence what it means to be human in the first place. In popular culture, androids being as yet too far beyond our technological horizon, the focus is on robots. But not just any robot. By and large, humanoid robots are news. Ones which just look like machines aren't.



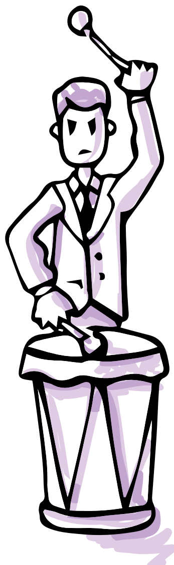
There are several larger themes which stories of robots as machines somewhere on the way to becoming people seem forever destined to explore. What are the ultimate relations between humans and the technologies we create? Will they dominate us (robot rebellion), succeed us (robot evolution), become part of us (cyborg evolution)? If they become our equals, must we cease to treat them as machines, and accord them rights?

It is the third theme which is spun into new variations in the context of work. Robots which are genuinely capable of work, but also unambiguously not human, can function as willing slaves. This is the most straightforward option, hence in some ways the least interesting. Literary interest ensues when ambiguity is restored. Are their owners blind to these slaves' needs? Do they suppress their own awareness, becoming themselves less human, in order to benefit from mechanical labour? Humanoid robots and androids, like aliens, figure in numerous explorations of slave culture, colonialism and class societies. This is fertile ground because so far all real historical experience has turned on either doing work oneself or appropriating the labour of others, either by direct domination – and dehumanisation – or by supposedly less oppressive employment.

So in parallel with exploration of the human–machine axis, robots in fiction also lend themselves to exploring divisions between capital and labour, masters and servants, and also the division of labour itself. Here there is a complication. An important feature of human work, and of many – but not all – actual robots is our invention of the division of labour. Humanoid robots are typically depicted as general–purpose machines, although they may undertake specialised tasks. (Digital computers, on the other hand, are inherently general purpose devices.) Real industrial robots are, often, almost literal realisations of the synecdochal insult which figures factory or farm workers as 'hands'. At any rate, they are isolated arms, with enough degrees of freedom to spray a car body panel, say, or weld a joint. Fictional robots are more often humanoid creations, for all the reasons already stated, although they may perform specialised tasks. Indeed, in many robot stories, apparently all–purpose robots are depicted occupying a single niche in the division of labour, without other apparent change in the society which has produced them, allowing the author to consider the character of the labour in question. What does the ideal servant, soldier, nanny, nurse, or sex worker actually need to be able to do?

Science fiction has explored this portion of robot story space both well and badly. There are many examples of robots doing particular jobs, but human characters normally interact with them one at a time. This is a way of evading the broader implications of the kind of capability that a robot secretary, say, or even a robot waiter or cab driver, imply. One example, from the exemplary author of robot stories Isaac Asimov, can stand for many others. In his late novel *Bicentennial Man,* Asimov re–works the robot becoming (as good as) human theme yet again, relating the long career of a robot butler who gradually assumes more and more human qualities, eventually starring in a court case in which he is accorded full human rights. But although the story covers 200 years, the rest of society appears unaffected by the advent of such advanced robots, or the technological descendants which would presumably appear over such a time span. This rather glaring deficiency may be due simply to lack of interest, or to a combination of Asimov's literary limitations together with a poor sociological imagination, but deficiency it certainly is.

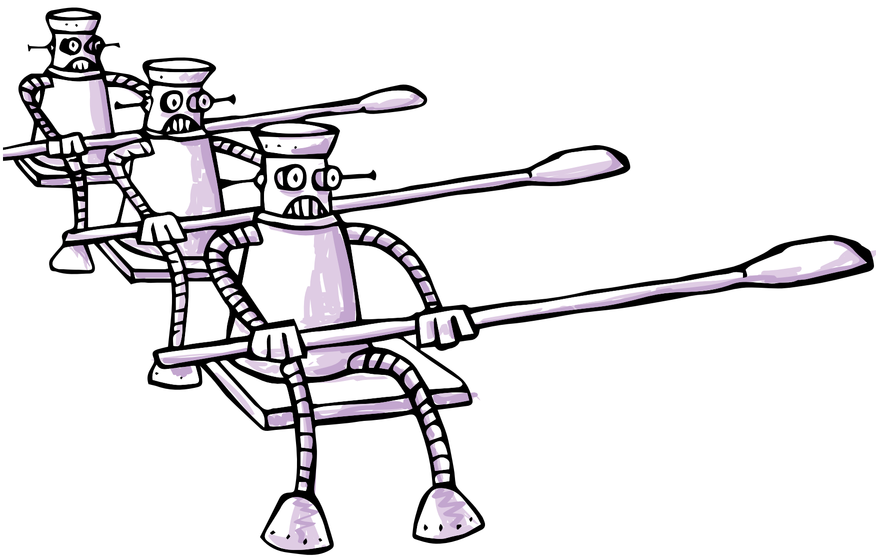
More interesting are stories in which robots filling particular niches are used to consider the qualities of particular kinds of work. A robot carer, for example, is doing emotionally charged work even if the tasks it carries out are largely mechanical – and will no doubt be invested with human qualities by its users even if it does not have them. Robot authors – depicted of course by writers who tend to feel that writing stories is fulfilling work – invariably appear as lacking in the kind of perception needed to write anything which is any good. As in a brief glimpse of the process of novel writing in *1984's* Ministry of Truth, automation would devalue the product:



> *“Julia was twenty-six years old... and she worked, as he had guessed, on the novel-writing machines in the Fiction Department. She enjoyed her work, which consisted chiefly in running and servicing a powerful but tricky electric motor... She could describe the whole process of composing a novel, from the general directive issued by the Planning Committee down to the final touching-up by the Rewrite Squad. But she was not interested in the final product. She ‘didn’t much care for reading,’ she said. Books were just a commodity that had to be produced, like jam or bootlaces.”*

This aside on the reduction of what would once have been creative labour to a mechanical procedure, points toward an area for speculation distinct from the robot/human dichotomy. It is concerned with other distinctions: between work and play; work and leisure; commodity production and craft skill. Industrialism offers alienated labour for a wage, but permits other kinds of work in the interstices of life. Its complement, consumerism, dehumanises through alienated leisure.

The themes running through stories of the rise of the robots which pick up these questions are economic, social and cultural. What is labour for? If robots take care of agricultural and industrial production, then theories of value fall apart. In the limit, robots offer costless production, and total economic transformation.



If work is no longer needed for subsistence, social transformation follows. If there is no need to work to live, then why work at all? The economic and the social transformations are bound together because the rise of the robots means there is no need to keep humans in paid employment. It may seem harder to imagine this when old right wing assumptions about shirkers, strivers and scroungers and the deserving and undeserving poor are being given new life. It even seems harder to credit speculations about automation leading to reduced working hours or early retirement when those in work experience their lives as time poor. However, fiction is still prepared to entertain the quasi–utopian idea: that the advent of capable robotics means that – after a transition of some kind – there is enough to provide for everyone's needs, employed or no, and no reason to deny the means of subsistence to those who choose not to work. But what will they do with their time? How will they organise their lives? Stories about robots and work in this vein are fairly easily led into reflections – profound or otherwise – about the meaning of life.

These themes seem an important aspect of the fictional treatments of robots. However, while I offer no comprehensive survey of the vast number of robot stories, it does seem clear they are not actually treated that often. But a small number of exemplary stories do show how they play out.

As with all the great themes of science fiction, which generally descend from earlier myths and stories, the starting point is hard to choose. The use of mechanisation, if not robotics, to allow creation of a society in which labour no longer dominates lives, is a feature of Edward Bellamy's somewhat socialistic utopia in *Looking Backward* (1888), for example, although he does not give details of the factories involved, simply making it clear that everyone is guaranteed a living with minimal working hours and early retirement.

There are endorsements aplenty of this idea, and dystopian variants in which everyone is thrown out of work by machines, from then on. However, when we come to robots as such, the obvious starting point is the work which introduced the term – Carel Kapek's celebrated 1920 play *R.U.R.* As is well known, the word he used – supplied by his brother Josef – was Czech for servitude or forced labour, pointing directly to the idea of willing slaves as the key to freedom from work.

Although the products of Rossum's Universal Robots are technically androids, their, as it were, robotic qualities are well in keeping with the themes of innumerable other robot stories. As the originator, Capek was in a position to muse on all the main themes at once. And so he did, invoking the Frankensteinian question about playing God, the limitations of a being without a soul, and staging the first of all those robot rebellions.

As robot suggests, *R.U.R.* also introduces the theme of roboticised work. In short, the conditions of industrial labour are inhuman, so Rossum's firm fashions inhuman workers. They will take care of production in future, liberating people from work altogether.

As Domin, who manages the robot production line, explains exultantly,

> *"In ten years Rossum's Universal Robots will produce so much corn, so much cloth, so much everything, that things will be practically without price. There will be no poverty. All work will be done by living machines. Everybody will be free from worry and liberated from the degradation of labour. Everybody will live only to perfect himself."*

He is aware a robot take–over of production arises from the capitalist logic that the best worker is the cheapest, and that this will be disruptive. But the result will be worth the cost.

> *"The servitude of man to man and the enslavement of man to matter will cease. Of course, terrible things may happen at first, but that simply can't be avoided. Nobody will get bread at the price of life and hatred. The Robots will wash the feet of the beggar and prepare a bed for him in his house."*

There are also not too subtle hints of the hubristic conviction underlying this humanitarian prospect.

> *"We cannot reckon with what is lost when we start out to transform the world. Man shall be free and supreme; he shall have no other aim, no other labour, no other care than to perfect himself. He shall serve neither matter nor man. He will not be a machine and a device for production. He will be Lord of creation."*

And hubristic it clearly is. This utopian vision is rapidly overtaken by events. Robots do all the work. People stop reproducing, through an unexplained biological internalisation of the demoralising effects of seeing robots taking care of business. And, in the end, there is a war in which the robots are victorious and humankind is eliminated.

The full trajectory of the humans–supplanted–by–robots narrative was thus sketched when robots made their first literary appearance. Amid the countless repeats with (often not very much) variation since, there have been a few more considered points about the effects of robot production.

Kurt Vonnegut's debut novel *Player Piano* (1952) uses the eponymous device as a metaphor for the displacement of a valued skill – playing music – by a machine. The work which is redundant in the novel is strictly factory work. The result of minimal labour factories, created on the back of a recent war effort, is a society divided between a small cadre of employed managers and engineers and a majority of unemployable workers. It was inspired, Vonnegut said, by his own experiences working for GEC after World War Two.

The former industrial workers have to choose between joining the army or doing make–work for the Reconstruction & Reclamation Corps (the Reeks & Wrecks). They are earning but otherwise find life unrewarding. The plot turns on a rebellion by humans against the machine, seeking to restore the dignity of labour. It fails.

A variant on the *Player Piano* style dystopia is Frederik Pohl's 1954 novella *The Midas Plague.* This offers a satirical inversion of consumer society. Robot factories produce so much stuff that the government enforces consumption quotas. The poor are obliged to meet them by cashing in their ration stamps. A bureaucratic state administers the rationing system, and allows some to earn the privilege of asceticism. They also have the time to do interesting things. The poor are too busy consuming to do anything else – alienated labour has definitely been replaced by alienated leisure.

The protagonist marries above himself, creating tension between him and his spouse, who cannot adjust to the treadmill of consumption he lives on.

In a drunken inspiration he sets the household robots to help them consume their quota – wearing out their own share of furniture and clothes. When this idea spreads, society begins to change – because the robots have their 'satisfaction circuits' adjusted to encourage them all to consume. The production system is saved by institutionalising this essentially pointless consumption.

So robot–assisted production is not a total disaster, but not a total success either. The same is true of a rather more subtle later story, Nancy Kress' short story *Nano Comes to Clifford Falls* (2006). As the title indicates, this centres on the newer technology of nanotechnological assembly rather than macro–robotics, but it is turned to the same end – automated production of, well, whatever you want.

The story is set in a small, isolated town which serves as a microcosm of the effects of this plenitude. They can be worked out a little more realistically because the device of delivering a small set of nano–assemblers to the town only abolishes one kind of labour – there is no machine intelligence apart from the programming of the nanomachines in this society, apparently, so administration, services, and care work are still confined to humans. This is emphasised by the protagonist, Carol, being the single mother of three children, her husband having deserted her. She watches warily as the townsfolk embrace the new tech, and larger social structures slowly disintegrate. *"It was kind of like everybody won the lottery all at once".*

The people who work in the local factory no longer have jobs. Most other people, from teachers to police officers stop going to work as well, and normal life unravels. But there are the beginnings of reorganisation, small scale, self–governing, with overtones of survivalism. Carol ends up living and working on a farm which has become a more or less self–sufficient community, populated by *"people who fled nano, like me",* and those who embraced it *"because it lets them do whatever they wanted to do before".* The latter include actors, scientists, *"one of them studying something about the stars. We also have a man writing fiction, an inventor, and, finally, a real teacher. Also two organic farmers, a sculptor, a man who carves and puts together furniture all without nails, and, of all things, the United States Chess Champion."*

If the moral of this selection of variously fulfilling work isn't clear enough, Kress has her narrator spell it out in not quite capital letters. *"I think nano is a sorter. The old sorting used to put the people with money and education and nice things in one pile, and the rest of us in another. But nano sorts out two different piles: the ones who like to work because work is what you do, and the* *ones who don't."* So there are still some optimistic, if not utopian possibilities from the end of wage labour.

So SF presents visions of passing labour over to robots, which are equivocal, to say the least – even if the transfer is restricted to industrial labour. Are there no genuine utopians, then? Or is Fredric Jameson correct that the utopian impulse has waned in the face of the difficulty of imagining alternatives to capitalism? Well, there is one fully–conceived system in which the place of work seems properly utopian – delineated in the late Iain Banks' series of novels set in the galaxy spanning Culture.

Imagining a full production system which supports a more or less utopian social structure requires a little more imaginary technology. The Culture is a complex creation – proceeding from the premise that venturing into space would inevitably promote less hierarchical social arrangements because of the difficulty of controlling others in a three–dimensional geography.

As the various societies that emerge develop, they solve the problem of production – together with their plethora of artificial intelligences, which we can equate roughly with robots in this context.

As Banks describes the result in an essay outlining how his society works...

> *"Briefly, nothing and nobody in the Culture is exploited. It is essentially an automated civilisation in its manufacturing processes, with human labour restricted to something indistinguishable from play, or a hobby."*

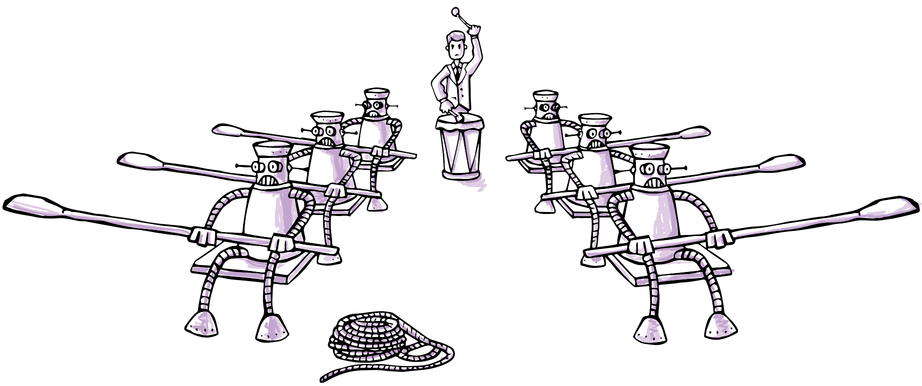
He acknowledges that making machines with human–like capabilities raises the problem of exploitation anew, but he finesses that, too, by careful application of technology.

> *"No machine is exploited, either... any job can be automated in such a way as to ensure that it can be done by a machine well below the level of potential consciousness; what to us would be a stunningly sophisticated computer running a factory (for example) would be looked on by the Culture's AIs as a glorified calculator, and no more exploited than an insect is exploited when it pollinates a fruit tree a human later eats a fruit from."*

And those who want to work, and to do work that is rewarding, are catered for as well. Apart from the hobbies or play – and art and games are both depicted in the novels – that happens partly by integrating their efforts into the production system. Again, Banks elaborates:

> *“Where intelligent supervision of a manufacturing or maintenance operation is required, the intellectual challenge involved (and the relative lightness of the effort required) would make such supervision rewarding and enjoyable, whether for human or machine. The precise degree of supervision required can be adjusted to a level which satisfies the demand for it arising from the nature of the civilisation’s members. People – and, I’d argue, the sort of conscious machines which would happily cooperate with them – hate to feel exploited, but they also hate to feel useless.”*

This seems a fair summing up of the dilemma which SF keeps worrying away at. If we abolish work, we abolish exploitation, but also the reward of exercising skill and ingenuity to contribute to the human community. The most tantalising question highlighted by these stories is whether we can dispense with one without sacrificing the other. It is still only a story, but it is heartening that at least one author says emphatically that the answer is yes.

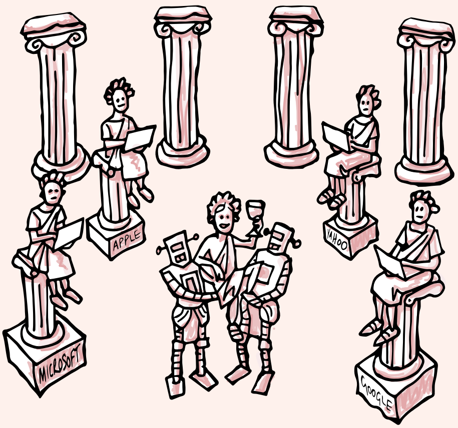


PART 4.

ROBOTS AND JUSTICE

SILICON VALLEY'S GOD COMPLEX

IZABELLA KAMINSKA



If you believe in the notion of God, chances are you believe that God to be all powerful, all knowledgeable and omnipresent.

What's more, being entirely subservient to and dependent on that being, you probably also believe yours is not to reason why but to do and die according to His will alone.

Resistance to the God power is futile in any case because rebellion leads only to the prospect of eternal incarceration in the fiery pits of hell. As a result it is only thanks to God's benevolence and mercy (which comes at his own discretion) that any quality of life can be assured at all.

What then is the difference between God and the ultimate capitalist monopolist? One who has, for example, come to dominate and own all resources, capital, patents, technological infrastructure and property?

BEWARE, BECAUSE SILICON VALLEY IS DEVELOPING GOD COMPLEX

Not that anyone should be surprised. If anyone's partial to delusions of grandeur and privilege it's going to be a bunch of tech billionaires working on artificial intelligence, bioengineering and autonomous craft.

But the idea does lead to an interesting thought experiment. Consider what really is a technological company's motivation these days?

What happens once everyone on earth becomes beholden to one company's devices, technology and IP? What can a technology company possibly hope to achieve next? More power? More dominance? More rent extraction?

What if there's simply no more market share or money to be had? The corporate's already more powerful than most major sovereign states. And its reach is international and all pervasive. What then might it crave next? Worship and adulation from its customers and users? Complete devotion to its vision? Godhood itself?

It's true that if anyone in the world has the power to turn themselves into God it is a modern technology titan like Google or Apple. The former even has famed inventor, futurist and seeker of eternal life Ray Kurzweil working within its ranks on such fantastical projects as robot armies and artificial intelligence.

Fitting, really, that the company's motto is 'Don't be evil'. And, for that matter, that Apple is named after the biblical fruit of temptation born of the tree of knowledge of good and evil itself.

Of course, if a tech giant was ever to achieve that degree of power, it would also imply the end of money, since everything by then would begin and end with the company in question. Instead of money it would be devotion and worship which would be exchanged for material gifts, information or access rights to heaven.

At this point, 'God Inc's' only concern would be the possibility of its monopolistic grip on everything being broken one day. If perchance, someone else discovered the elixir of immortality as well.

Wouldn't our super monopolist then have an interest in suppressing all paths that could lead to that eventuality? Would it not have an equal interest in keeping everyone else utterly misinformed?

In fact, would it not, perversely, have an interest in purposely obscuring and suppressing the abundance it itself had created. Handing out scraps for us mere mortals to fight over in a bid to keep us too distracted or poor from pursuing the knowledge we need to compete?

Okay, it's a far-fetched tale. But so too are reports of contrived wage pacts between technology titans, patent wars and DDoS attacks on competitors – none of which stops any of them from being true.

The idea that the stage may be set for the emergence of exactly such a power, isn't consequently too outlandish.

Awesome technology breeds awesome power. And today's technology is more God-like than anything we've seen before. Unless that power is consciously prevented from being allowed to concentrate, whether by government, the masses or anti-trust authorities, it's not at all implausible that all roads will lead to the formation of a technological power almost indistinguishable from God.

In that context, the curious thing is that according to economist Robert Gordon, the rate of technological advancement has been slowing rather accelerating over the last decade. Gordon says this is because most of the *"low hanging technological fruit"* has by now been picked. Future advancement depends on impossibly complex discovery, meaning technological stagnation is the much more likely path from now on.

But is it really so?

One needs only to read about Google robots, self–driving cars, drones and 3D printing to arrive at the conclusion that this is very clearly not what's happening at all. In contrast to Gordon's prediction technology seems very suddenly to be on the move again, and violently so.

While it's tempting to ponder what's behind the revival, it's possibly more important to figure out what was behind the slowdown in the first place.

Remember, also, that Gordon was extrapolating forwards from trends recorded up until 2007.

In whose interests, after all, would technological stagnation or regression have been? A Luddite's? A power hungry monopolist's?

Or perhaps mostly in the interests of those who stand to lose irrespective of whether the gains of technology flow towards just one hand or are distributed more widely. Namely, the established elite.

All of which makes this latest spell of technological advancement so particularly interesting. None of these anti–technology interests have gone away. If anything they've become more pronounced.

So why is it that technology seems finally to be breaking free?

There are really only two possibilities. One is that the information age has allowed knowledge to be shared on such an unprecedented level that technological progress is now impossible to repress. The second is that a handful of companies have pulled so far ahead of the pack, and accumulated so much wealth, they can now burn cash on fanciful projects without any concern for risk or return.

Either way, if the hype delivers on even half of its predicted potential, the Asimovian age of self–driving cars, drones, self–learning machines, nanotechnology, manageable matter and bio–engineering could soon be upon us.

If the results are not monopolised and rationed by just one hand, this could lead to economist John Maynard Keynes' famous 1930 prediction of an era of economic abundance and leisure time for all.

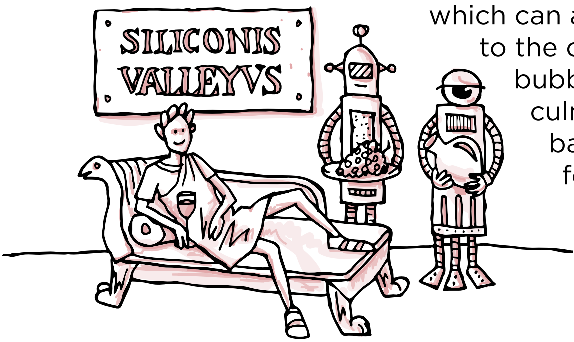
The problem for us economic creatures, however, is that both structurally and psychologically we are unprepared for the scale of the social change that awaits us if this is achieved. As Keynes himself noted, once the economic problem is solved, mankind will be deprived of its traditional purpose, exposing it to a potential nervous breakdown unless something else is found to fill the void.

Abundance denial may at this point prove more appealing and digestible to the masses.

This is ultimately because a scarcity-focused mind-set is very hard to overturn. Society has been hard-wired over millennia to reward those working towards overcome scarcity with status and privilege. Abundance changes this entirely. 'Adding more' no longer qualifies as something worthy of reward, implying a radical rethinking of how society must allocate wealth and value from thereon.

Small surprise some would prefer to ignore the value shift entirely, and cling to old-fashioned ways of doing things – no matter how harmful they may be for the greater population – just because that's what we've always done, or because the idea that value doesn't have to be inextricably linked to toil is far too alien.

The loss of jobs to technology is consequently viewed as a hardship, not a liberation from the shackles of labour. A supply side shock is interpreted as a depression, not a gift. More worryingly, a lack of investable opportunities for abundant capital is viewed as a conspiracy to undermine established hierarchy and not as an opportunity to spread wealth without social cost.



Seen from this light, the 2008 financial crisis, which can arguably be traced back to the collapse of the dot-com bubble, can be judged as the culmination of a decade-long battle between two opposing forces. One representing the established capital elite, who strive to preserve the status quo, favouring technological progress only as long as it benefits their social standing. The other, their challengers, who favour technological progress at any cost, whether it threatens to concentrate power or to redistribute it more widely.

By 2000, it arguably became clear to the established elite that if the rules of capitalism were allowed to play out to their natural conclusion, they would be losers no matter what.

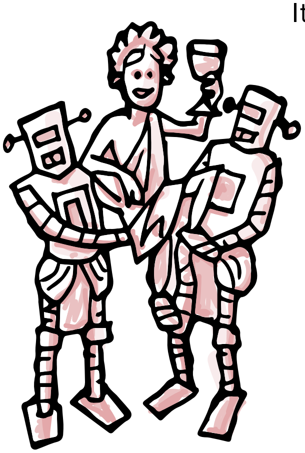
Which is why from 2000 onwards incumbent powers had more of an interest in thwarting technology than championing it – something most easily done by creating high entry costs to market and buying out challengers whenever they arose.

Indeed, viewed from that perspective, it's easy to conclude that what the stratospheric valuations during the dot-com bubble were really signalling was that by that point in the technological cycle, an all-or-nothing monopolistic race to the top had already begun.

Until it was proved otherwise, all stocks could consequently exist in a quantum state of infinite or zero value.

For valuation, this posed something of a Hofstadter-Moebius loop – the contradictory condition which caused a breakdown in Arthur C. Clarke's HAL9000 super computer. A company could hold both infinite social value or none at all, depending entirely on the popularity of its stock, and its capacity for use as an acquisition currency, rather than as an income generator.

As soon as a cohort of select companies broke into the lead, this all-or-nothing nature of the value system was exposed. Prices of everything other than the leaders' stock were vapourised. Which of course was a profound shock to those who found they had been backing the wrong horse.



It was also too great an existential crisis for an old order which ultimately desired little more than the preservation of the current hierarchy, especially when pursuing 'more' increasingly came with the risk of losing everything.

And so it was that by *2001* capital's interests became entirely disconnected from technological progress.

Instinctively capital oriented instead towards the control of anything solid, rentable, or scarce. Out went investments in technological stocks that could undermine incumbent power and in came investments collateralised by good old–fashioned bricks and mortar or anything tangible like cars, commodities or infrastructure.

What followed was the understandable tendency for capital to organise (albeit unwittingly) to stifle capacity, innovation and multi–factor productivity instead. A period of mega M&As, leveraged buyouts, self–inflicted resource squeezes and bubbles was initiated. Industrial consolidation was epitomised by RBA's $98.5 billion acquisition of ABN AMRO in 2007 and AT&T's $72.7 billion acquisition of BellSouth in 2006; leveraged buyouts by KKR and TPG's $48 billion leveraged acquisition of TXU in 2007. The self–inflicted resource squeeze, meanwhile, by the reserves crisis of Royal Dutch Shell in 2004 and the bubble economy by the general outperformance of house prices and commodities.

All this, of course, in the context of a globalisation trend – the only permissible form of wealth distribution to an old order more interested in preserving domestic hierarchies than international ones.

The line between real consumption demand and investment demand became blurred as a result, obscuring the real potential for return in the process.

For a long time markets mistakenly believed a growth model focused on asset price appreciation and rent extraction (rather than real economic earnings) could be sustainable for the long term. But, of course, just like a game of Monopoly ends when players run out of money to pay the dominant landlord, so too must an economic value system that waives technological progress in favour of drawing rents from its privileged ownership of scarce resources or property.

Though, this was by no means the only factor contributing to the collapse. An equally important – but under–appreciated role – was played by the rise of the networked collaborative society, typified by the Wikipedia and open source movement. This, for the first time, began to challenge old capital's ability to repress technology. Those doing the disrupting, after all, were doing it on their own time, motivated by passion not financial gain. This detached the creative destruction process from the cost of capital completely.

Demonetised and price insensitive, technology was now free to contribute to the global stock of knowledge–based wealth and a value system linked to open rather restricted access, rather than a conventional bottom line, making breakthroughs very hard to monetise within the rules of the established zero–sum capital system.

Inevitably, technological efficiencies born out of the collaborative movement began to impact incumbents soon enough, either by undermining revenues directly, as per the challenge posed to the conventional media, entertainment and publishing industry by public content, or through margin compression thanks to the elimination of information asymmetries, leading to greater consumer bargaining power.

All well and good, apart from the fact that by crushing revenues it also crushed jobs, and with it the ability of normal leveraged folk to make their mortgage payments. When Federal chairman Alan Greenspan raised rates in 2004, he magnified these pressures, choking the asset–backed growth model and in so doing paving the way for global financial crisis of 2008.

In the name of stability, as we all well know, it fell upon the government to socialise the resulting asset–backed losses – and thus to prop up the value of capital which might otherwise have been destroyed completely. To this day many consider that act anathema. But really, the lack of inflationary consequences suggests the capital wasn't necessarily valueless at all, but rather, more suited to collective ownership than private ownership from the onset.

This, plus continued support for 'social value' from central banks, has helped to create an economic environment in which technological forces can thrive again. But, as Larry Summers recognises with his secular stagnation theory, it has also renewed the incentive for old capital to protect its privileged positioning through the monopolisation of scarce resources and assets.

How effective the latter's campaign will be depends entirely on how quickly technological forces will be able to compensate for the cornering in question, and make the scarce un–scarce. Something which in itself depends on the government's ability to support social value without encouraging the emergence of a God–like technological monopolist by accident instead.

THE SECOND SHIFT IN THE SECOND MACHINE AGE: AUTOMATION, GENDER, AND THE FUTURE OF WORK

GEORGINA VOSS

2014. *Becoming an HVA is a one-time deal, they told her: almost impossible to ever be the same weight, have the same haircut or hold the same pose ever again, so what gets captured in hologram is preserved in amber forever. Not that it's something she necessarily wanted to go through twice – as an actress she's well-versed in performative perkiness, but it's a whole other thing to be upbeat and cheery when you have to be as still as a statue. Shoulders back, spine straight, hands clasped in front of her, lips and cheeks and eyes doing the heavy lifting of projecting emotion with not a twitch of movement elsewhere. Her muscles were in agony by the end of the day. Still, immortality of a sort – "No-one will ever know your name" they told her, but of course her timeless inflexible twin would greet her every time she passed through the departure gates at Heathrow, reminding her to bag up her liquids.*

1. INTRODUCTION

If 47 per cent of total US labour will be automated in the coming two decades then who, exactly, will have to find new jobs? Fears of technological unemployment are not new: driven by technological change, there is a long history of Schumpeterian 'industrial mutations' which make forms of work, and workers, redundant. Much of these discussions centres around the relationship between technology and skills: whilst nineteenth century manufacturing 'deskilled' by substituting skills for simplified tasks; twentieth century electrification increased demand for both skilled blue-collar workers to operate machinery, and white-collar production workers. The 1960s computer revolution paved the way for 'Lousy and Lovely' jobs: high-income cognitive work and low-income manual occupations, and associated growing wage inequality.

Through adaptation and education, human labour has – so far – prevailed; new types of jobs slither up through the cracks of the emerging economic structures. Many fears around robots and technological unemployment have focused on the differences between robots and humans, the way the former is often presented fictively as the means to replace the latter, the skills–gap between the two. Humans are messy, fleshy beings who come in a limited range of sizes, weight and strength with limbs that only bend in certain directions, and annoying tendencies to *"fulfil a range of tasks unrelated to their occupation"* – eating, sleeping – affecting their cognitive perception.

But humans are not a homogenous group, and labour and skills are not equitably distributed. Women experience work differently from men, both in terms of who performs it, how it is valued, and even what 'work' is considered to be. In the past decade, the gender gap in global labour markets has worsened: female unemployment rates are higher than male and are expected to stay that way until at least 2017. Technologies impact differently on female labour: mechanisation disaggregated the cottage industry of weaving, installing male spinners as textile machine operators whilst their wives and children *"often toiled for these piecemeal labourers".*

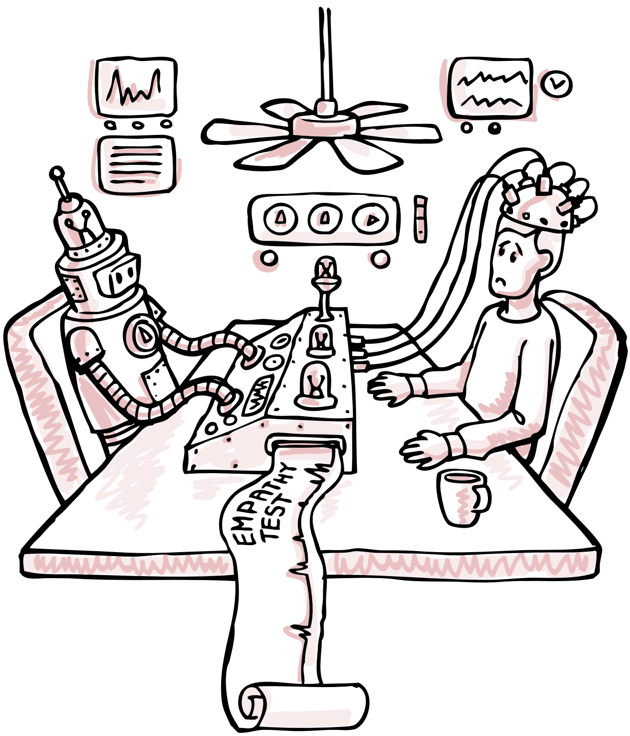
Dry analysis of the proficiencies which robots are predicted to take up focuses on neutral skill sets – 'Social Intelligence', 'Perception and Manipulation' – abstracting from who possesses or is in a position to learn them, what types of jobs they are associated with, and how they might vary along gender lines. What might the robot uprising look like for women?

2. ROBOTS IN THE MARKET ECONOMY

Work is split down gender lines, with women being generally more limited in their employment choices than men. 'Pink collar jobs' are characterised by low pay, low status, stress, and routine and monotonous work. They are clustered into semi– and low–skilled roles , and are often subservient to more highly–skilled positions: secretaries to managers, paralegals to lawyers, factory worker to foreman. More high–status work can be clustered into 'pink ghetto' spaces where women can't progress beyond senior management into the boardroom.

This segregation has rarely been based on physical attributes – historically, women have taken on physically intensive tasks in sites such as agriculture. Instead, it has been shaped around expectations of the role that women are expected to play in society. Pink collar work is not women's work which happens to be low status – it is low status because women do it. Women are more likely than men to leave work due to family commitments, and more likely to do unpaid childcare and housework. Combining this with paid work in the market often necessitates finding a job which is flexible or part-time; despite the rise of workplace flexibility policies, large swathes of the labour market simply do not offer this type of elasticity. Certain sectors – notably STEM and finance – remain highly male-dominated with associated working cultures. What flexible labour is available is often aligned with precarious temporary contract work which is less likely to carry protections such as unemployment benefits; in 2011, almost 60 per cent of zero-hour contract workers were female.

The characteristics of repetitive low- and middle-skill pink collar tasks – *"organising, storing, retrieving or manipulating information*



or executing exactly defined physical movements in production processes" – are also those most likely to be done by machines. Computerisation has thus far focused on routine work involving explicit rule–based tasks, and current generations of robots are at their most efficient, far more so than human workers in constrained environments. With dark irony, these middle–service jobs which were created by technological advancements may now be replaced by further technological change. In East Asia, assembly jobs in clothing and electronics have mostly been taken by women who left low–productivity agricultural employment; whilst this has increased their economic independence, it has also made them more vulnerable to jobs losses from increasing mechanisation and automation.

But it is not only routine jobs which are at risk. For some time, non–routine roles have been seen as the final bastion for fleshy humans whose brains are jam–packed with cunning neurons and actuators to perform abstract tasks that require persuasion, negotiation, even creativity; activities that previously have been hard to specify as instructions in code. Non–routine tasks also have manual aspects: visual and language recognition and situational adaptability around environmental changes (for example, preparing spaghetti carbonara for four, or moving from a tiled floor to a carpeted one). And they are also under threat: sophisticated algorithms could, according to one forecast, replace 140 million knowledge workers whilst advancements in sensors and manipulators increasingly allow robots to perform non–routine manual tasks such as performing surgery and operating driverless cars.

Yet human labour persists, and so do the gendered patterns which underpin it. Engineering and science are deemed to have low susceptibility to computerisation due to the high degree of creative intelligence that they are purported to require; likewise, occupations dominated by social intelligence – education, healthcare, management, finance, arts, media – are also low–risk. These 'safe jobs' are, however, predominantly white–collar jobs in areas still characterised by high wages and high levels of education in areas that are – as before – male–dominated. And as before, it is the low–status service facing jobs in these areas which are likely to vanish first: whilst paralegals – over 80 per cent of whom are female – are at high risk of replacement, lawyers – over 70 per cent of whom are male – are not. Instead, new breeds of professional white–collar management roles encompassing technological know–how are emerging. Arguing that *"robots need managers too"*, Lauren Weber describes how the managers who previously trained temps to fill boxes, now need to oversee both the robotic automation processes as well as the mechanics on hand who tackle errant machines.

Many of the jobs resilient to computerisation are not just those held by men; but rather the structure and nature of these jobs are constructed around specific combinations of social, cultural, educational and financial capital which are most likely to be held by white men. Other factors also intersect in labour markets: race, like, gender is also a socially constructed category which contains inherent power differences in social systems. In many cities, white women earn more than men of colour overall; and white women and women of colour have different experiences of local labour markets, with the former benefiting from the social constructions of race (for example, that white women are more likely to be seen as professionals). The different effects of computerisation on men and women are not only about gender differences, but are symptomatic of larger power structures across society and the ways in which certain forms of labour are valued.

2018. ***The advantage of 'puppeteering', as they call it, is that it's invisible; the disadvantage is that it's invisible and the pay is awful. The beige suits are meant to make you sink into the background whilst the duck–egg blue MoppSy cleans the floors and the rose–pink FluffSy does the same on the bookcases; like they tell you at training, the machines are the stars of the show, not you. All you have to do (the area manager says) is lay down the trail of stickers so they know which path to take, carry the machines up and down stairs, and listen for 'unwelcome noises'. In practice, it's like supervising a petulant child that sometimes does what you ask but mostly leaves corners untouched and a trail of grease and water around hard surfaces. Engineering skills are a must for puppeteers – FluffSy's tend to cark it when humidity levels are too high, and you can't wait for an overpaid tech–support guy to come out all the way across the city when each house needs to be cleaned to a two–hour guarantee. Best to crack open that awkward side panel, poke around in the FluffySy's guts with some fine copper thread and, if you really have to, hack the system to override the temperature–safety constraints. Time is money!***

2. ROBOTS ON THE SECOND SHIFT

Work is not confined to capitalist labour markets. An enormous amount of work that women do happens on the 'second shift' – unpaid cleaning, tidying, cooking, childcare and general household management which women do the bulk of, in addition to their paid 'day' jobs. This is 'reproductive labour' which helps to enable paid labour in the market–based workforce to take place by taking care of the household. It is often invisible, because it happens out of the public eye; and viewed as low value because it happens beyond the market economy and has culturally been viewed as tasks which should be performed by women who are married to men as part of the 'free' services which are part of being a wife. Reproductive labour is often closely allied to affective labour – work which creates value by shaping emotional experiences, and which is often also found in other 'women's' roles around care–giving.

There is a long–standing relationship between the second shift and technologies. Initially driven by the demise of the servant class, devices such as vacuum cleaners, food processers and sewing machines began to find their way into the home from the late 1910s onwards. As mains electricity became prevalent and women left the home for paid employment, these devices multiplied and shifted in function to include hairdryers, toasters and coffee–makers. They were sold on their labour saving properties, with adverts promising women that the devices would *"automatically give you the time to do what you want to do".* Whilst forms of labour were changed – for example, electric washing machines taking over from washboards, tubs and wringers – the introduction of domestic technologies actually resulted in women spending more time on housework as standards grew higher. The more people who had washing machines meant higher expectations that clothes would be washed more often. As the devices were not autonomous or trouble free, their users still needed to provide them with service support through monitoring and maintenance.

But labour in the home is not always confined to its occupants, and reproductive labour also takes place under market conditions. As women entered (paid) work, much of their second shift labour was turned over to less affluent women, many of whom are migrants and women of colour. Like other forms of pink collar work, this market–based domestic labour continues to be low paid, low valued, precarious, routine, and often extremely physically intensive. Barbara Ehrenrich describes how the female workers for cleaning services companies are required to follow rigidly fixed and ordered patterns of work to be performed as rapidly as possible:

> *"When you enter a room, mentally divide it into sections no wider than your reach. Begin in the section to your left and within each section, move from left to right and top to bottom."*

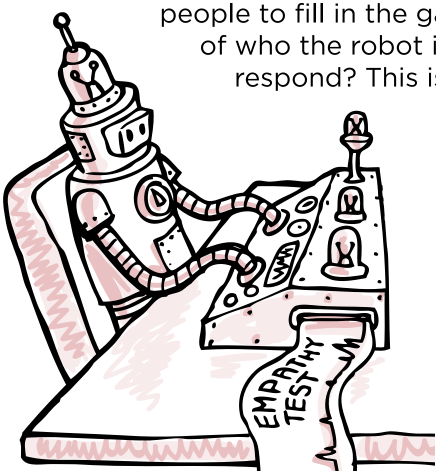
The technologies used in industrialised domestic work are not elegant devices designed to fit into a stylish home, but cumbersome machines which use the physicality of human bodies to compensate for their own limitations: heavy, fourteen–pound vacuum cleaners which are worn, back–pack style such that the mobility of the human worker only serves to propel the machine around the house.

The market for personal and household device robots is growing by 20 per cent annually, with machines taking on tasks including mopping, lawnmowing and gutter–cleaning. But service support will still be needed – though robots will endeavour to clean up mess, human workers will still be required to clean up after the robots. Roombas, for example, are contradictory machines which inspire great anthropomorphised affection from their owners whilst also being remarkably inefficient at actually reducing domestic labour – Roomba–owners have reported that they accommodate for its weaknesses by tidying the house before setting the machine free on the floors, and also following it around as it works to ensure that it doesn't get trapped under chairs. It is difficult to imagine that such fondness will be transferred to the human domestic workers whose role it will be to support the machine; who, by the nature of their work are low–status, invisible and intended to stay 'below stairs' and out of the way by their employees.

***2090.** Testing takes place in a small drab room that smells of sweat; lots of different small drab rooms, of course, but all alike in their own sweaty way. For obvious reasons, it got nicknamed many years ago as Voight–Kampff or VK – 'You been VK'd yet?' – and even the company men call it that. It usually only takes about half an hour and is, ironically, administered by machines. 'Have you always dreamt of a white wedding?' 'You're in a café and you get served full-fat milk with your tea, although you asked for semi-skimmed. Do you complain or just drink it?' That long rambling question about how to comfort a screaming toddler comes up about a quarter of the time. Your answers determine whether the Agency will place you with a job, but no-one knows whether getting through means that you've passed the test or failed it.*

4. ROBOTS IN THE LABS

Robots do not emerge from engineering labs as sleek neutral entities, ready to impose on an unsuspecting labour force. Beyond their technical capabilities, the roles and the ways that they interact with humans are carefully engineered into their very being – and much of this design is framed, both intentionally and unintentionally, around stereotypical cultural norms about who 'men' and 'women' are and what they do. Human–Robot Interactions (HRI) research explores what types of interactions robots are intended to have with humans. A starting point for these investigations is that to function with maximum efficiency, robots must take on certain characteristics which allow people to fill in the gaps and build a mental model of who the robot is – what does it do? How will it respond? This is described as Computers as Social Actors theory, in which humans ascribe agency and personality to computer-mediated interactions – in other words, that humans instinctively treat computers like humans. But which humans? If a robot is intended to induce affection, it will be designed one way; if fear, another – even if the core purpose of the machine remains the same. Roboticists



are advised that 'companion robots' for children should not be designed to carry features which are likely to frighten them, such as an overwhelmingly large size or *"creepy appearance".*

What induces fear, affection or trust in humans is, however, loaded with user expectations, which in turn are embedded in a variety of culturally–specific norms and stereotypes. People quickly form mental models based on what they know best, namely other people: age, race and gender provide the most salient social cues, and are deeply fundamental parts of how people understand and respond to each other. If a robot is expected to embody female traits, how will it be designed? And what expectations are being collected under the category of 'female'?

Physical traits are obvious ways of denoting gender, although the ways in which this has played out in robot design scenarios appear to have been dropped in from the 1950s. In a field which continues to be male–dominated, gender is often approached using what Jennifer Robinson dryly describes as *"common sense knowledge…of femininity in relationship to masculinity (and vice versa)".* 'Female' robots have been so denoted through pink lips, long hair and a higher pitched voice, and by name and gender verbal introduction. Robot designer Tomotaka Takahashi complained of the difficulties of engineering his Female Type robot because he argued that the feminised version would have to have a slimmer torso, which presented a challenge in terms of fitting the internal mechanisms into the body. Finally, gender can also be prompted by occupational identity: even if it has a gender–neutral appearance, users will still assign a gender based on what tasks the robot is doing.

Once robots have been cued as male or female, user expectations will fill in the gaps with men and women particularly likely to anthropomorphise voices that correspond to their own gender identity. 'Female' robots are seen as more likeable, trustworthy, persuasive and communal; whilst 'male' robots are perceived as being more threatening and agentic, although the praise they give is taken more seriously. Men also tend to feel psychologically close to robots that have a 'male' voice, and are less willing to take instructions from the car's SatNav if it has a 'female' voice.

As *"a robot may be mistakenly viewed as medically competent if it is dressed in a lab coat and wearing a stethoscope",* so gendered robots have certain skills ascribed to them. 'Male' robots are assumed to be better at repairing technical devices whilst 'female' robots are assumed to be more suited to domestic and caring services. Roboticists themselves have fallen in line with these lines of thought. In their 2005 paper, eliciting information from people with a gendered humanoid robot, members of the Human–Computer Interaction Institute at Carnegie Mellon University built design scenarios based on the notion that *"women are more knowledgeable about dating forms and social practices, and they have more social skill than men do".*

What is worrying is how these reactions are blandly, neutrally, co–opted into design processes simply as a way of inducing a certain type of user reaction. Gender norms are not challenged, but instead reproduced in the name of machine utility. Security robots which are coded as 'male' are deemed more useful – and thus acceptable – than with a 'mismatched' identity. Male roboticists predict that their female robots will find work in classic sites of affective labour in the service sector: in bars, information booths and 'upmarket coffee shops'. Some have contended that creating robots which appear distinctly 'male' or 'female' is preferable in certain contexts:

> *"A mechanic's helper robot, if stereotypical, would be male. If we wanted this robot to have minimal and efficient conversation with users about what tools they need, how to assist, and so forth, then the mechanic's helper should be male. Suppose that we wanted users to provide more information, to explain themselves, to be redundant. This might be a design goal if the robot was not a mechanic's helper robot, but a general assistant and not specifically designed for the task. Then, the robotic assistant should be anti–sterotypic for the task, ie. Female for the mechanic's helper."*

Members of the robotics community have raised concerns that their peers are uncritically reproducing, reinforcing and perpetuating stereotypes attached to gender and work. Whilst some have described how developing 'female' assistive robots would be useful for facilitating bonding with infants, others have voiced their worries that children raised with these female robotic caregivers may then have their beliefs influenced about the nature of gender roles; for example that women are naturally nurturing and *"derive immense joy from menial household chores".*

5. CONCLUSION

The impact of robots on the future of labour for women looks particularly grim – not because of any inherent feature of the technologies themselves, but because their predicted sites of application appear to sustain and even exacerbate existing gendered structural inequalities in the labour markets. Recommendations around improving gender conditions in these markets focus on wider policy interventions including better infrastructure to relieve the burden of housework; provision of care services for children and the elderly; and public campaigns to challenge gender stereotypes. Computerisation appears to offer solutions for the first two of these, but only as a techno–fix – the intervening technologies of assistive and domestic robots are still likely to require support from traditional tranches of female service workers, albeit with added technical skills. They do little to consider the labour conditions of these workers: are they pink, blue or white collar jobs? Do they afford their own flexibility around childcare or paid maternity leave? Nor do they specifically address wider social and physical infrastructural elements necessary to address these problems more equitably such as electricity supply or state support for these services. Dishearteningly the current strand of robotics research, with its focus on the use of stereotypes to shape human–robot interactions, appears to actively uphold gender typecasting. Technologies themselves are not inherently arbiters of employment or job loss but are made so through the political context in which they emerge. It should be no surprise that the shiny surfaces of our new robot workforce do not dazzle our eyes with a bright new future, but simply reflect back existing gender inequalities and power imbalances.

WHY MACHINES ARE NOT SLAVES

EDWARD SKIDELSKY

In 1891, Oscar Wilde made an unlikely foray into political economy. The result was *The Soul of Man under Socialism,* surely one of the strangest contributions to the genre ever published. Among its many striking projections is a vision of machines as a new slave class:

> *"Machinery must work for us in coal mines, and do all sanitary services, and be the stoker of steamers, and clean the streets, and run messages on wet days, and do anything that is tedious or distressing. ... The fact is, that civilisation requires slaves. The Greeks were quite right there. Unless there are slaves to do the ugly, horrible, uninteresting work, culture and contemplation become almost impossible. Human slavery is wrong, insecure, and demoralising. On mechanical slavery, on the slavery of the machine, the future of the world depends.[1]"*

There is much that is true and prescient here. In agriculture and manufacturing, mechanisation has led to the disappearance of much (not all) *"ugly, horrible, uninteresting work".* The service sector, traditionally a human preserve, is rapidly following suit. Secretaries, receptionists, cashiers and bank clerks have all recently joined the roll call of the obsolete. Others will no doubt follow shortly. It is now possible for a citizen of the affluent world to spend many days pleasantly without having to interact with a human being at all.

Most economists are comfortable with this development. They dismiss as a naive error the claim that machines are 'stealing our jobs'. Under competitive market conditions, they say, the purchasing power liberated by automation should be sufficient to re–employ any lost labour in new (and probably more interesting) enterprises. For a long time, this thesis seemed to hold true. Throughout the 50s and 60s, employment remained high even as productivity grew. However, two recent developments have served to temper optimism.

The first is the phenomenon of ‘jobless growth’. Productivity in America grew by an average of 2.5 per cent annually from 2000 to 2009 – the fastest rise since the 1960s, thanks mainly to the computer revolution. Yet during this same period, no new jobs were created. In fact, employment sank by 1.1 per cent, despite a population increase of 30 million.[2] Similar trends have been observed across the developed world. The conclusion is inescapable: machines are stealing our jobs. Nor is this surprising when one reflects that recent gains in productivity have accrued mainly to the very rich, who have sunk them in investments. Two decades of growth did little more than pump a speculative bubble.

Mechanisation has not only destroyed some jobs, it has degraded others. This is particularly evident in the service sector. Call operators, shop assistants, receptionists, even doctors and teachers, are subject to an increasingly harsh regime of supervision and control, facilitated by computer technology.

(The phenomenon has been dubbed 'digital Taylorism' in honour of the pioneer of scientific management, F. W. Taylor).[3] Procedures are standardised. The scope of judgement and trust is narrowed. 'Best practice' is 'rolled out' across the board. The effect on all concerned is depressing. Labour is de–skilled and its bargaining power eroded – a factor in growing income inequality, as Frederick Guy shows in this volume. And patients, students and customers are made to feel that they are objects of a purely impersonal process, for which no one is responsible and no one cares.

All this is far from Wilde's vision of servile machines ministering to leisured humans. What went wrong? The problem is partly one of economic organisation. If work really is dwindling, it would seem sensible to provide people with an income independent of it – a so–called basic or citizens' income. But this has not happened. We remain wedded to a modified version of the old Soviet doctrine: *"He who does not work, neither shall he eat."* As a result, the leisure that should have been available to all is visited upon the few in the grim form of unemployment.

But even if we could solve the organisational problem, Wilde's vision of mechanical slavery would still not be realised. For the fact is that machines are not slaves, or anything like slaves. They are incapable – for deep, not just technical reasons – of adequately replicating human service. They can do it, but they do it badly. (Anyone who has tried to ring NHS Direct or eat sushi from a conveyer belt will know what I mean.) Why is this? Why are machines, which worked such wonders in manufacture, of such doubtful utility when it comes to service? That is the question I want to answer.

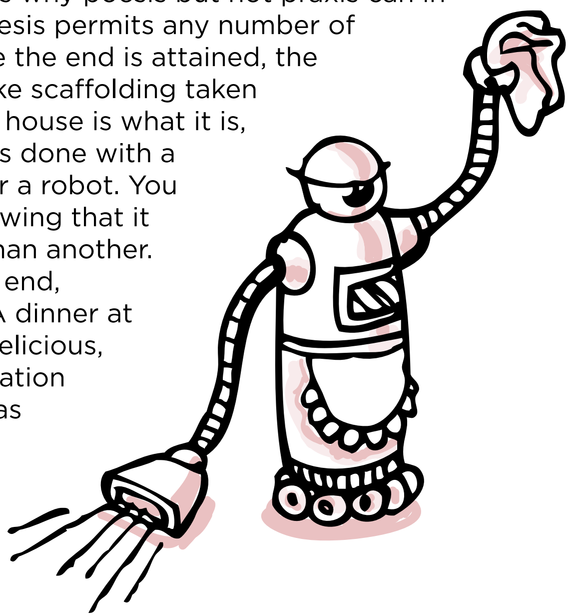
POESIS AND PRAXIS

What exactly does the distinction between goods and services amount to? The distinction goes back at least to Adam Smith and is enshrined in most national accounts. However, mainstream economic theory pays it little heed. From its point of view, goods and services are both commodities subject to the general laws of supply and demand. The differences between them are purely cosmetic.

I think there is an important distinction to be drawn here, though it doesn't quite correspond to the conventional distinction between goods and services. The distinction that interests me is between two forms of human action, which we can designate using the names first given to them by Aristotle: poesis and praxis.[4] Poesis is standardly illustrated by the production of a vase, shoe or some other artefact, but it is not limited to this sort of thing. Cleaning a house or creating political turmoil in Iraq also count as poesis, though what they aim at is not a material object but a state of affairs. In general terms, an action is poesis if it is a means to an end external to itself, so that it could be replaced, in theory if not in fact, with some other action. If one could clean a house by reciting a magic formula, one would presumably do so. The important thing is that the house gets cleaned.

If poesis has an external end, the end of praxis is simply good praxis itself. Games and the performing arts are the clearest examples. Whatever else he aims at, a chess player must at least aim to play chess well, otherwise he doesn't count as playing it at all. Cooking for friends, giving advice and giving a gift are also praxis, for they aim, in the first instance, at success in the specific kinds of activity they are. Praxis is an expression of particular skills and dispositions on the part of the agent. In Dante's happy phrase, it is the disclosure of the agent's own image.[5] Hence it cannot be delegated. You cannot farm out to some third party the choosing and giving of a gift, or if you do, the gift is no longer a personal token of affection but something more like a bribe. And that is a case of poesis, not praxis.

It should be clear from this why poesis but not praxis can in principle be automated. Poesis permits any number of means to a given end. Once the end is attained, the means drops out of view, like scaffolding taken down after the job. A clean house is what it is, regardless of whether it was done with a broom, a vacuum cleaner or a robot. You would not feel cheated knowing that it was done one way rather than another. But where action is its own end, mechanisation spells loss. A dinner at a friend's house, however delicious, is diminished in one's estimation by the knowledge that it was bought from Waitrose. The meal remains the same, but the gesture is altered.



The poesis/praxis distinction is the interesting core of the manufacturing/service distinction. It explains why most manufactures can be mechanised without loss whereas most services cannot. Cost and quality being equal, no one cares whether a chest of drawers was made by robot or by hand. But imagine discovering that a favourite Horowitz recording was in fact generated on a computer after his death. Something would surely be lost, even if the deception was perfect. Appreciation of piano music rests, writes philosopher Denis Dutton, upon *"an unstated assumption: that it is one person's ten unaided fingers that produce the sound. The excitement a virtuoso pianist generates with a glittering shower of notes is intrinsically connected with this fact."*[6] Unlike most pop music, a classical CD is essentially the record of a human act. It is a product of praxis, not poesis, though it is classed as a good, not a service, in the national accounts.

The services of the teacher, doctor and nurse also fall under the heading of praxis. However, there is an ambiguity here, which creates an opening for the mechanisers. Because education aims at a state of knowledge, it can be thought of as a 'mere means' to this state, pursuable in a multitude of different ways. That is a mistake, though. A surgeon might cause you to understand calculus by fiddling with your brain, but he could not be said to have taught you calculus. Teaching aims not just to foster a certain state but to foster it in a certain way. It is essentially rational instruction; it proceeds by means of explanations, examples, descriptions and stories. Mechanised teaching, with its apparatus of multiple-choice tests, MOOCs and so forth, is inherently second-rate, though it may be unavoidable in certain circumstances. In the same way, doctoring and nursing are not just means to the end of health but forms of care. They can be mechanised up to a point, but only at the expense of quality.

Not all services are praxis. Cleaning, as has been said, is a form of poesis, as are most routine clerical jobs. Many of these services have already been mechanised, without any great loss. Others resist mechanisation for purely technical reasons. It is hard to build a robot that will sweep in corners or under the bed. But it will happen sooner or later, and when it does, only the redundant cleaners will bemoan it.

THE EROSION OF PRAXIS

I have said that certain services are intrinsically unsuited to mechanisation. It does not follow that they are incapable of mechanisation. The first is a normative, the second a factual claim. There are no principled barriers, technological or economic, to the mechanisation of education, medicine or art. On the contrary, there is every incentive to press ahead with it. Replacing labour with capital is, after all, what capitalism is all about.

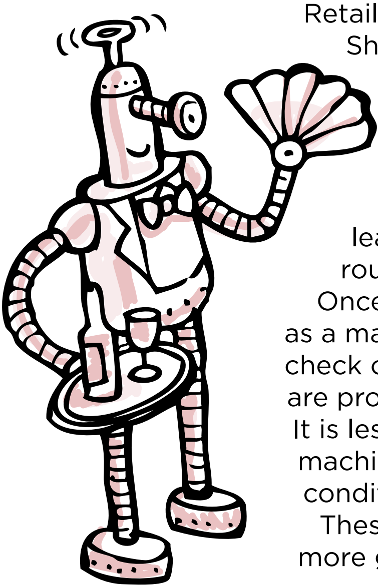
The supposed recalcitrance of services to mechanisation was the basis of a famous economic theorem, known as 'Baumol's cost disease' after its author, W. J. Baumol. The theorem's original reference was to the performing arts, but it applies to all services in which 'the human touch' is ineliminable. Its basic idea is very simple. In a progressive economy, sectors that cannot realise the benefits of technology will find themselves at an increasing disadvantage relative to sectors that can. In live performances, Baumol wrote,

> *the performers' labors themselves constitute the end product which the audience purchases … Whereas the amount of labor necessary to produce a typical manufactured product has constantly declined since the beginning of the industrial revolution, it requires about as many minutes for Richard II to tell his "sad stories of the deaths of kings" as it did on the stage of the Globe Theatre. Human ingenuity has devised ways to reduce the labor necessary to produce an automobile, but no one has yet succeeded in decreasing the human effort expended at a live performance of a 45 minute Schubert quartet much below a total of three man-hours.*[7]

Baumol's conclusion is somber. Given stagnant productivity, the only way for theatres and music companies to keep down prices is to squeeze the wages of their artists. This squeeze might be endured for some time, thanks to the 'psychic benefits' of the profession, but not for ever. Ultimately, the best people will leave the arts for more remunerative jobs. The only solution is for governments to finance the arts, and social services more generally, at a level commensurate with their rising costs. Happily, they can afford to do this, since the same rise in productivity that generates the cost disease will also fund the taxes required to combat it. Whether the tax-paying public can be persuaded to accept this solution is, of course, another matter.[8]

Baumol viewed the cost disease as endemic to the service sector, which is why he could see no solution to it other than increasingly generous government subsidies. An old-fashioned humanist, he could not foresee music, healthcare and education being subjected to the Fordist methods prevalent in industry. But that is what has happened. Existing forms of service have been mechanised, and tastes have shifted from less to more highly mechanised forms. Both trends tend to the erosion of praxis and its replacement by poesis.

The mechanisation of a service usually proceeds in a number of steps. First, procedures are standardised, often with the help of computers ('digital Taylorism'), and with the unspoken goal of replacing skilled by unskilled labour. This then sets the stage for the elimination of labour altogether. Modern day banking is a case in point. Bank managers once issued loans and overdrafts on their own authority, relying on their local knowledge and professional good sense. Later, they were confined to relaying the decisions of a centralised computer system. But this could only ever be an interim stage, for a person whose sole function is to communicate the verdict of a machine is in principle replaceable by a machine. Today, the role of the bank manager has all but disappeared, and we communicate with our banks either over the internet or via call centres in India.



Retail has followed a similar trajectory. Shopkeepers once made decisions about what to stock and how to price it and many other things. Some still do, but they are a tiny fraction of the total. In supermarkets, these powers were long ago arrogated to central management, leaving those on the shop floor with the routine task of checking out purchases. Once this step was taken, the next followed as a matter of course. Why not ask customers to check out purchases themselves? Many shoppers are probably grateful for this latest development. It is less dismaying to deal with an actual machine than with a human being reduced the condition of one.

These examples raise a couple of points of more general interest. In both banking and retail, mechanisation has not only reduced the total quantity of work but shifted whatever remains onto the consumer. It is we who must navigate our bank's website or scan our purchases through the automated checkout point. It is also we who must book our tickets online, assemble our furniture, paint our houses, and many other tasks that used to be performed by professionals. One should not be nostalgic for the poverty that made these forms of service widely affordable. But it is nonetheless striking that the life of a middle–class Indian is far richer in personal services than that of his British counterpart, though perhaps poorer in material goods.

It is a measure of the unpopularity of mechanised service that those who can will pay a large surcharge to avoid it. Most banks offer their wealthier customers a 'premium' service with a personal account manager – i.e. the same bank manager who was once available to everyone. And though small, independent shops still exist, their prices put them beyond the reach of most shoppers. We are seeing the emergence of a two–tier market: personal services for the rich, mechanised services for everyone else. The spread of the terms 'boutique', 'concierge' and 'bespoke' to refer to all kinds of high–end service is a revealing index of this development.

The last few decades have not only seen the mechanisation of existing forms of service but a shift of taste from less to more mechanised forms. Baumol was of course right about Schubert and Shakespeare, but he failed to foresee that classical music and drama as a whole would sink in popularity relative to other, more easily mechanisable cultural forms. The modern pop single is a substantially computer–generated product. A singer may be called in to supply the 'vocals', but the rest is the work of technicians. Their skill level is high, but not as high as that of classical musicians. And you don't need as many of them. Even live performances are now mainly pre–recorded, with singers and musicians adding only the occasional embellishment, if indeed they are singing or playing at all. The labour costs of this kind of music are low (even taking into account the salaries of the star performers), meaning that prices are correspondingly cheap: a factor, among others, in its mass popularity.

The burgeoning taste for reality TV can also be understood as a response to Baumol's cost disease. Here the trick is to replace the paid labour of actors with the unpaid labour of members of the public, whose vanity makes them willing collaborators in their own exploitation. Again, such television is cheap to produce – a guiding consideration in this era of tight competition and declining budgets.

Even in our taste in scholarship is being surreptitiously shaped by the imperatives of mechanisation. The critic Franco Moretti has pioneered a technique he calls 'distant reading'. This consists, in a nutshell, of running computer searches over thousands or millions of digitalised texts with a view to establishing correlations, trends, etc.[9] No single book is read in the way it was intended, from beginning to end. In the hands of a Marxist maverick like Moretti this technique yields some startling results, but its deeper tendency is to transform literary studies from a humane discipline requiring subtlety, learning and skill into an essentially industrial operation, ripe for economies of scale. As such, it is calculated to appeal to university funders and administrators, who have shown a marked enthusiasm for Moretti's approach.

"Lass uns menschlich sein!" said Ludwig Wittgenstein: *"let us be human!"* The thought is simple, but not banal. Being human, it implies, is not vouchsafed merely by membership of the species Homo Sapiens. It is something we must strive for, something we can lose. Today, the struggle to be human is in large part a struggle against the mechanisation of service, or more precisely of praxis. Let's hope we emerge victorious.

1. Oscar Wilde, The Soul of Man and Prison Writings (Oxford: Oxford University Press, 1990), p. 15-16.
2. See Erik Brynjolfsson and Andrew McAfee, Race Against the Machine (Lexington, Mass.: Digital Frontier Press, 2011), pp. 29-36. The figure for productivity growth refers to the non-farm business sector.
3. For a powerful indictment of digital Taylorism, see Simon Head, The New Ruthless Economy: Work and Power in the Digital Age (Oxford: Oxford University Press, 2003).
4. See Aristotle, Nicomachean Ethics, 1140b5: "For while making (poesis) has an end other than itself, action (praxis) cannot; for good action is itself its end."
5. "For in every action what is primarily intended by the doer, whether he acts from natural necessity or out of free will, is the disclosure of his own image." Quoted in Hannah Arendt, The Human Condition (Chicago: University of Chicago Press, 1958), p. 175.
6. Denis Dutton, The Art Instinct: Beauty, Pleasure, and Human Evolution (Oxford: Oxford University Press, 2009), p. 187.
7. William J. Baumol and William G. Bowen, Performing Arts: The Economic Dilemma (Twentieth Century Fund, 1966), p. 164/
8. See W. J. Baumol and W. E. Oates, "The Cost Disease of the Personal Services and the Quality of Life", in Ruth Towse (ed.), Baumol's Cost Disease: The Arts and other Victims (Cheltenham: Edward Elgar, 1997), pp. 82-92.
9. Franco Moretti, Distant Reading (London: Verso, 2013).

TECHNOLOGICAL CHANGE, BARGAINING POWER AND WAGES

FREDERICK GUY

Have the new technologies of the information age contributed to the rise in earnings inequality?

Earnings are part of income – specifically, they are income obtained from work, as opposed to income from the ownership of property or from transfer payments received from the government. Sometimes I'll simply call them 'wages', though earnings also include the salaries and more exotic forms of compensation achieved by, for instance, corporate executives and investment bankers.

Relative earnings are determined in part by supply and demand conditions in the labour market, and in part by the success that different workers – as individuals or in groups – have in bargaining for a greater share of output. In this chapter I am concerned with the latter: how has modern technology affected the relative bargaining positions of the low paid and the high paid? The bargaining I'm talking about is sometimes a formal process of offer and counter offer, but in other cases it's just a way of describing the ability of an employee to get the employer to pay a bit more.

The technology in question is mostly information and communications technology (ICT). Organisations can't function without some form of ICT – and here we must include writing, and typewriting, as well as telecommunications, file cabinets as well as digital storage.

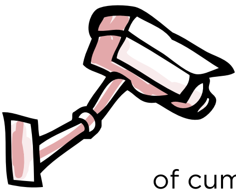
The current, microelectronics-based generation of ICTs has over the past thirty years fundamentally transformed relationships within organisations.

I'll consider three different ways in which the application of a new ICT can affect the bargaining power of an employee. Adopting the language of agency theory, we can call the employee the agent, and call whoever is supervising the employee the principal. A new use of ICT in an organisation may improve the ability of a principal to monitor exactly what an agent is doing; improved monitoring leads, for reasons I will explain below, to a reduction in wages. It may also increase the range of financial consequences associated with choices that a particular worker must make on the job, and this will in turn increase that worker's wages. Finally, application of new technologies may make it easier for workers – individually or in groups – to disrupt a production process or value chain, and thus harder for them to use the threat of disruption to bargain for higher wages.

All three effects can work both ways: reduced monitoring/increased wages, and so on. Peter Skott and I have argued, however, that since the late 1970s these effects have gone mostly one way for workers and the other for executives, and for this reason ICT has contributed to rising earnings inequality. The typical 'flexible' business of today is one in which most workers are more closely monitored, make fewer choices of consequence to their employers, and have fewer opportunities to hold up production, than their mid-twentieth century equivalents; the executives who run the same companies make choices with far more riding on them; all of these changes are the result of the same new ICTs, and often the same applications of these ICTs. Skott and I call this power-biased technological change (PBTC). Unlike the supply-and-demand explanations for increased earnings inequality, PBTC is something that can't be offset by improved education and training; what steps might be required to offset it are beyond the scope of this chapter.

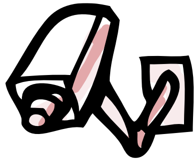
Let us consider examples of each of these three effects, starting with monitoring. Until a few years ago, employers of long-distance truck drivers had only a vague idea of where their employees were most of the time: the trip between A and B could be disrupted by traffic – or a simple stop for tea, and the employer was none the wiser. Today, the driver's employer can buy a black box which monitors the engine continuously; it can follow the location of the truck using GPS; it can even follow the black box data in real time via satellite. These monitoring solutions cost money, but they are widely used. Prior to these technological developments, for an employer to obtain comparable information about a truck's whereabouts would have required employing a second driver and vehicle to follow the first – a prohibitively expensive measure.

We see the same sort of technologically–facilitated monitoring in the many areas of customer service which have been switched from face–to–face interactions (in, say, a bank branch), to call centres; in call centres, as we know, 'calls may be monitored for quality purposes', which is to say for the purpose of monitoring employees. Again, this is technology making it much cheaper for the employer to check whether an employee is using time effectively and using it in the employer's interest.



Consider, also the retail till. Here we can compare two generations of monitoring technology, introduced roughly 100 years apart. The cash register was invented around 1880; although it underwent ongoing technical refinement, through generations of cumbersome mechanical, to less cumbersome electro–mechanical, and finally to electronic devices, its basic capacities remained unchanged until about 1980: it monitored the total amount of money the operator had taken in from customers (cash intake had to equal the machine's total of the printed receipts given to customers). This made it harder for an employee to steal cash from the employer, and thus facilitated the growth of large stores and chain stores, which depend on having employees collect cash at various locations throughout opening hours. It was still easy, however, for employees to collude with friends in the theft of goods: the employee could 'accidentally' misplace the decimal, ringing in a 90 per cent discount. Around 1980, bar codes and mini–computers suddenly gave the cash register new monitoring powers, and these 'under–rings' became impossible.

All of these improvements in monitoring – of truck drivers, of customer service workers, and of retail clerks – have been followed by reduced relative wages for employees in these areas. This cannot be simply a matter of skill bias – the skills required to drive a truck, to pick up and deliver goods, have not changed. The association between cheaper and better monitoring, and lower wages, is consistent with the body of economic theory known as



agency, or principal-agent, theory; it is convenient here to think of it in terms of one simple variant agency theory, efficiency wage theory. Efficiency wage theory deals with situations in which paying higher wages is a way of getting employees to work harder so that, up to a point, paying higher wages leads to higher profits. I say 'work harder' as shorthand for 'acting in the interest of the employer while on the job, even if it's not in the employee's personal interest': this includes greater effort, but can also include things like not stealing. The theory tells us that, other things being equal, employees who are costly to monitor will be paid more. Where new technologies – in particular, information and communications technologies (ICTs) reduce the cost of monitoring, we should expect wages to fall.

Monitoring what an employee does, however, only helps the employer to the extent that the employer knows what they want the employee to do: to work without unauthorised tea-breaks, to ring in the correct prices, and so on. Often, however, the employee knows things that the employer does not: local or specialist knowledge about the different possible ways to do the job, and the likely outcomes. This brings us to another dimension of the agency problem: how much does the employer have riding on choices the employee makes? One explanation for the high pay of company executives, for instance, is that so much rides on their choices: a bad merger decision can severely damage a company (Royal Bank of Scotland and ABN AMRO; Co-op Bank and Britannia; Hewlett Packard and Autonomy...) and if you were a shareholder you'd be willing to pay executives a lot, if you thought that was a way of getting better decisions.

Mid-twentieth century companies came to be viewed, in the 1980s, as inflexible, bureaucratic dinosaurs. Managers today like to think their companies are, in contrast, agile, lean, learning organisations. We need to take this management chest-beating with a grain of salt, but there is also more than a grain of truth in it. Largely because of the ICTs at their disposal, mid-twentieth century organisations were very slow to change. This meant that there were fewer big-stakes choices facing their executives: companies weren't so often sliced and diced into saleable parts, with the associated big deals of mergers, acquisitions, and divestments; competitors were also slow-moving, and product life cycles were longer. Top executives, with much less riding on their daily choices, were paid much less than they are today.

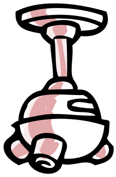
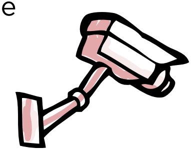
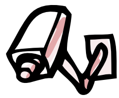
The cumbersome, paper–based, coordination and control technologies of the mid–twentieth century also left a great deal more to the discretion of lower–level employees. The worm's eye view of a company's coordination and control system is that it is a set of rules – procedures, plans, budgets, job descriptions – with which one has to work. Below the executive level of an organisation, the weakness of coordination and control systems can actually empower individual middle managers, and even production workers.

In what way were the old coordination and control systems weak? We think of the mid–twentieth century as the heyday of Taylorism, or Scientific Management: of doing things by the book. It was all that, but the book was often wrong. A plan is never better than the information systems that inform it. Even a fairly good plan or budget becomes bad as market conditions and technology change, unless the systems are such that executives can continually update the plan and put the updates into effect throughout the organisation. Plans are necessary to keep different employees and departments working in a coordinated way toward the same end, but when the plan is a bit out of kilter, the profitability of a company often depends on those in the lower – and middle – ranks choosing to do something that looks sensible, rather than following the book.

Today, the same monitoring systems that keep an eye on the productivity of individual truck drivers, retail clerks and call centre workers, also provide information which enables executives to fine–tune the instructions these workers, and their supervisors, are given – what is the best route, the most efficient way to pass goods over the scanner, the most effective script for each type of customer inquiry or complaint; as a result, there are many more cases in which the employer knows exactly what choices they want an employee to make. This changes the agency problem for those employees: when the employer did not know what choice the employee should make, it was worth the employer's while to give the employee some kind of incentive to use their local or specialist knowledge to make a choice that was in the employer's interests. Often, that incentive was the prospect of continued employment, with wage rises and promotions, if the employee's choices proved to be sound over time. To the extent that the employer knows precisely what the employee should be doing, the agency problem reduces to just monitoring the employee's behaviour.

Since the same technologies that improve the specification of instructions also improve the monitoring of employee behaviour, improved ICT puts a double squeeze on the earnings of employees. At the same time, improved ICTs make the organisation into a more flexible instrument for the executives. This gives executives a greater range of choice, and also contributes to a more demanding competitive environment – since the executives of competing companies have benefited from these same improvements. In many industries, the marketplace becomes a turbulent battleground between highly paid executives, with their armies of low-paid employees marching in close order. There are, of course, many employees who are not on either end of this dichotomy – skilled employees whose choices matter, but who are not executives deploying large numbers of employees and resources: these are the people in the shrinking middle of the earnings distribution.

Let us turn, now, to the vulnerability of production to deliberate disruption. This vulnerability came from another aspect of the inflexible production and information systems of the early-mid twentieth century: flows of goods and of information, essential to the interdependent operations of a company or a value chain, had to go through many bottlenecks. Individual workers – and, more critically, organised groups of workers – were able to obstruct these flows, slowing or halting very large production processes. The threat of such obstruction was the source of considerable bargaining power.

Take the mass production of cars, which requires the synchronised production and assembly of thousands of precision parts. As this process developed in the decades following 1910, a car company such as Ford or General Motors would employ hundreds of thousands of workers, producing parts and sub-assemblies and then entire vehicles. This led to a situation in which the workers in a single GM transmission plant in Michigan were able, in 1937, to bring numerous large

factory complexes to a halt simply by sitting down at their stations, refusing to move and refusing to work. Having demonstrated their ability to disrupt such a vast and profitable value chain, the workers' union was in a position to bargain for higher wages. Something similar was seen in the network industries of the day. Telephone companies then depended on manual switching of calls, and all calls had to be routed through a few points. America's long-distance telephone operators could (and did) bring services to a halt simply by standing up (since, unlike the car factory workers, they sat down to work) in unison. Similar actions were repeated, or threatened, in other industries and in other countries: there several decades in which unions were powerful and the earnings of production workers rose in real terms.

As dramatic and powerful as these instances of collective action were, early–mid twentieth century systems also had bottlenecks that were quite sensitive to the disruption by individuals. Ford's first automobile assembly line opened in 1913, but by 1914 Ford was paying assembly line workers what seemed extravagantly high wages for unskilled work. The reason, simply, was that the need for assembly line operations to be carried out in sequence at a common pace made the failure of a worker to report, on time and sober, very costly to Ford; it was worth paying an efficiency wage to secure such reliability. Nor was it only physical parts that flowed down a single, interruptible path: the information critical to coordination and control was written on paper, which followed fixed paths from desk to desk, filing cabinet to filing cabinet: many a clerk was in a position to either slow down the vast corporate mechanism, or to speed it up.

Today's technologies of coordination and control – the fruit of the microprocessor revolution – have made it practical to replace many of these bottlenecks with multiple paths. More flexible mass production processes mean that if one factory is disrupted, another can change the product to fill its place. Telephone calls and other electronically transmitted information can be automatically switched down any of numerous paths between sender and receiver. A customer service request does not await action by a particular individual, but is queued in an electronic system. The actions of dispersed employees in an organisation, rather than being committed to written records and then to summaries of those records, filtering in this way slowly upward through the layers of hierarchy, are now logged automatically to become raw material for the management information system. Improved information and communications systems have also lowered the cost of outsourcing functions as varied as office cleaning, manufacturing, and IT. This means that in many companies, spheres of work once in the hands of teams of in–house specialists can now be put out to competitive tender from a number of alternative providers.

All of these multiple paths deprive production workers and middle managers – as individuals and as groups – of opportunities to use hold–up, the threat of disruption, to bargain for higher wages. At the same time, the proliferation of possible paths, the continuing choices between outsourcing and in–house provision, have further expanded the set of choices facing executives, increasing their pay in the ways discussed above.

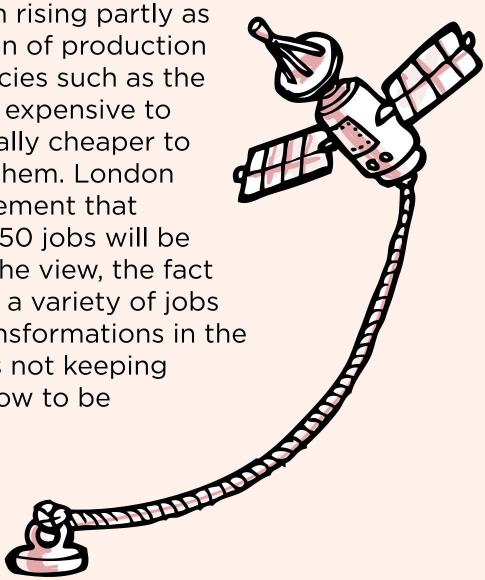
To sum it up: the improvements in information and communication technology since the 1970s have enhanced the ability of corporate executives to monitor what employees are doing, to specify what employees should be doing, and to move information and materials flexibly down multiple paths. All of these developments have reduced the bargaining power of a large set of production workers and middle managers. All of them have also made the corporation a more flexible instrument for its executives; a marketplace of such flexible corporations, in competition, is a more turbulent place.

WORKERS' EXPERIENCES OF THE ROBOT REVOLUTION

TESS REIDY

Computers are replacing humans across many industries, and, well, we're all getting very uneasy. We are losing the checkout assistant to the self-service scanner, the airport ticket desk to a kiosk, and the factory floor worker to the machine. Surely the robot driving instructor and the touch-screen waitress aren't far off? Whilst technology is responsible for creating jobs we might never have imagined five or ten years ago, it has also eliminated many more. For the time being, it seems that, in most instances, computers are substituting humans in routine intensive jobs – that is, occupations mainly consisting of tasks following well-defined procedures that can easily be performed by computer programs.

Alan Milburn, the Government's social mobility advisor, points out in his report *State of the Nation 2013,* that inequality and poverty keeps on rising partly as a result of increasing automation of production processes. Others fear that policies such as the living wage could make it more expensive to hire workers, meaning it is actually cheaper to buy the technology to replace them. London Underground's recent announcement that tube ticket offices will go and 750 jobs will be lost is one example. Whatever the view, the fact remains that many people from a variety of jobs are experiencing significant transformations in the way they work and education is not keeping up. People need to be taught how to be flexible and adapt their skills if technology means constant change.



Since leaving school aged 16, Helen Smith, now 40, has been working as a customer service advisor for a high street bank. Above all, she wanted a secure job and one in which she could speak to people and provide a helpful service.

Many high street banks are pushing customers to use ATM machines that can now handle a large number of deposits, withdrawals and transfers – tasks that used to take a significant fraction of a cashier's time. Over the last year, Smith has seen a reduction in the number of counters in her branch and a move towards encouraging the customers to use automated machines instead. *"We have a lot of customers that don't particularly like it – and I do understand that,"* she said. *"We have customers that get quite angry and abusive towards the staff in the branch. So for example, we say 'how can we help you' and they say 'you can find me a f***ing teller'".*

"The long-term fear that I and a lot of my colleagues have, is that reducing counters means less staff, so what does that mean for our jobs?" she asked.

> *"If there are less people using the branches because they are being pushed to use other automated methods then does that mean the branches closing? We are being encouraged to push customers to bank in a certain way and so are we talking ourselves out of a job?"*

In November 2013, Barclays Bank announced cuts of more than 1,700 staff from customer-facing branch-based roles. Cashiers, personal bankers, operational specialists, branch managers and assistant manager roles will be cut throughout 2014. The bank claims that the way people access banking services is changing rapidly, with more using smart phones and other technology. Unite the Union have criticised the plans, branding it a 'colossal mistake'. They say customer service could suffer as a result. Dominic Hook, Unite national officer said: *"These employees deliver high levels of service that customers of the bank benefit from. Such a massive reduction will be very detrimental to the bank and will also be hugely challenging for the remaining staff. Consumers want to engage with*

knowledgeable, highly experienced, professional staff. Members in branches will be facing a period of considerable uncertainty in the current harsh economic climate."

Like Smith, supermarket checkout assistant, Leanne Appleyard, 32, feels uncertain about her job. In the last six months, all the major supermarkets have cut back on traditional checkouts to make way for self-scan tills amid claims that they are faster and more convenient.

Appleyard says it worries her when people choose the self-service tills even though she is free to serve them. *"I often have to call people to let them know I'm free, I don't think they can see that I'm here sometimes, but it surprises me that I have to wave at them to let them know."*

As for her future, she said: *"I don't think people are losing their jobs because of it at the moment, but I do wonder how much it will change."*

For many, self-checkout machines neatly illustrate the limits of computers' abilities to mimic human skills. In a survey, 84 per cent of respondents admitted to needing staff assistance when using a self-service checkout, while 60 per cent preferred using traditional staffed tills. More than 40 per cent of shoppers experienced technical problems, triggering the voice warning of an 'unexpected item in the bagging area'. This happens a lot, said another checkout assistant, Vimal Gupta, 24.

> *"Some people do not know how to use the self-service tills properly. They put the items on the wrong side and then it doesn't work. I think they find it frustrating, so it's easier if we do it for them," he said. "But generally, if they know how to do it then it works fine."*

The shop workers' union Usdaw is critical of these changes.

> *"There are a number of potential issues with self-service tills, including the fact that they differ from one store to another, they can be temperamental and that the queuing system isn't always obvious. If one shopworker is put in charge of a number of self-service tills and if they are helping a customer there can be a delay in helping another. This can cause customer frustration and it is generally the shopworker who bears the brunt of any resulting abuse and undue stress."*

Meanwhile, in the public sector, IT is also changing the way people work. Sue Mustoe, 50, has been a secretary at a GP's surgery for more than 25 years. She chose the job because she likes talking to patients. Over the last few years this aspect of her job has started to disappear because of developments in technology designed to save time, improve patient care and eliminate paper records.

As of the last three months, patients can now, if they want, make an appointment at home by logging in to the online surgery system and then walk through the door, check themselves in on an automated check in service, and go and see the doctor. After their appointment, patients can order prescriptions on a screen, which then get sent electronically to the chemist, and so, throughout all this, not actually speak at all to the secretarial staff at the desk. *"This loses the personal touch and it's the one downside of the system and I suppose it's the one element I don't like as much, but fortunately, many of our patients choose to speak to us as people here as they are not quite so keen to do everything automatically,"* she said.

One element, which is implicit so far, is the value of human contact. Loneliness and isolation is a huge and growing problem and technology can both help and undermine. For instance, Skype is bringing people together and robots helping severely disabled people to communicate, but also having a few words of conversation in the bank or at the doctors surgery can keep a person afloat – or will we one day have robot 'friends'?

Despite this, Mustoe does think there are advantages to the new systems. *"It frees up the receptionists up a lot to do other things that need to be done,"* she said. *"When there is a queue it is ideal that people will come out of the queue and check themselves in."*

Doctors and secretaries can now see online which hospital has the shortest waiting list and make appointments for patients straight away, so it is all done electronically and the patient gets the notification on the same day. According to Mustoe, *"That part of it is a much better system and it also gives the patient a choice of where they want to go."*

Mustoe says that doctors can now dictate letters and notes straight onto a computer system.

> *In the past, tapes were always being passed around and we used to leave messages for the doctors in books and then we would have to wait for the doctor to come in to our office and look at them. Now, instead of having to wait for the doctor to come in, we can leave them electronically so this means the doctors are reading the messages as and when they come in. I think it's probably better for everyone. Old-fashioned appointment books used to take forever to go through.*

Although it helps that hospital notes are available almost instantly and can be looked up on a screen or booked online, one of the disadvantages with this is that it is harder to actually speak to someone to discuss problems if they arise. *"Phones ring for ages,"* said Mustoe.

For Mustoe, while the system is working, the advantages are there. But when the computers go down it descends into chaos.

> *We haven't got a list of patients because it's all on the computer and so we wouldn't have a list of appointments. That's happened before.*

Elsewhere in the public sector, processes are changing. Custody Sergeant Nick Perks, 45, has been working for the police for ten years. He thinks that developments in technology have improved his work as it allows the police to keep information for longer and share it between the different agencies. *"I can open custody records here as opposed to faxing them over to other stations,"* he explained.

> *The computer systems have got better and better as time has gone on, and now, anyone can access prisoner logs and update them at the same time, so we can work on the same documents without having to close them, so it's much quicker.*

The main benefit for Perks is that information is easily available to everybody in the force. Officers now have remote access to up-to-date systems, so that if they are out on the street they can look at photos of people on the spot and see who they are. *"You don't have to go back to the station so it does make it more efficient,"* he said. "Plus, we've got a new national radio system, so if you have a big event such as a protest where many forces are involved you can all use the same radio system."

Overall, Perks thinks these systems have sped up police work and improved the way the force operates. The only downside, he says, echoing the experience of doctors' staff, is when the computer systems fail; there is no paper back up. "So as long as it works it's fine. The reliability of it is absolutely crucial – it must work or else it all falls apart."

Jay Khan, 36, has been a minicab driver for four years.

> *"We have GPS on all our cars and so the office know where all drivers are at all times unless we are in a dead signal zone. We have to let them know if they are going to go to the shops or go or stop off for a coffee."*

"This way they know where we are and they don't even have to talk to us," said Khan, who thinks the new system is far better than the old radio system.

The taxi firm has also introduced a text service that sends customers a message when they book a car and lets them know when it arrived. *"Texting everyone makes the customers feel safer so they know the make and model of the car rather than getting into any old car,"* he said.

Elsewhere, technology is also having a positive impact on the way people work. Nicola Jennings has been a cartoonist and illustrator for a national newspaper since 1987. Developments in technology in her profession have changed the way she works entirely. It has given her the freedom to work remotely – and the freedom to undo mistakes. *"I can work anywhere in the world now, it has changed dramatically because I can just email the work in and also because the newspaper and magazines are online, as well as in print, I am now working in a multimedia medium and a 3D medium rather than just a 2D medium so now there is the potential for art animation as well, rather than just a still images. So it's very exciting,"* she said.

These days, Jennings draws on an expensive digital tablet on the computer using software that emulates pen and ink. *"Some of it I still do the old–fashioned way, but if I'm animating, I use the computer. It's much sharper if you use real pen and ink and then I scan it onto the computer because it's so fabulous to be able to undo. It's very exciting indeed."*

Jennings thinks that, in the main, you can tell the difference between work done on the computer and that drawn on paper. *"You can usually spot it,"* she said.

> *"With the computer software you can make an illustration look absolutely exactly the same as if it was hand drawn but because the computer has different possibilities you end up going with that and therefore the computer gives you a slightly different style."*

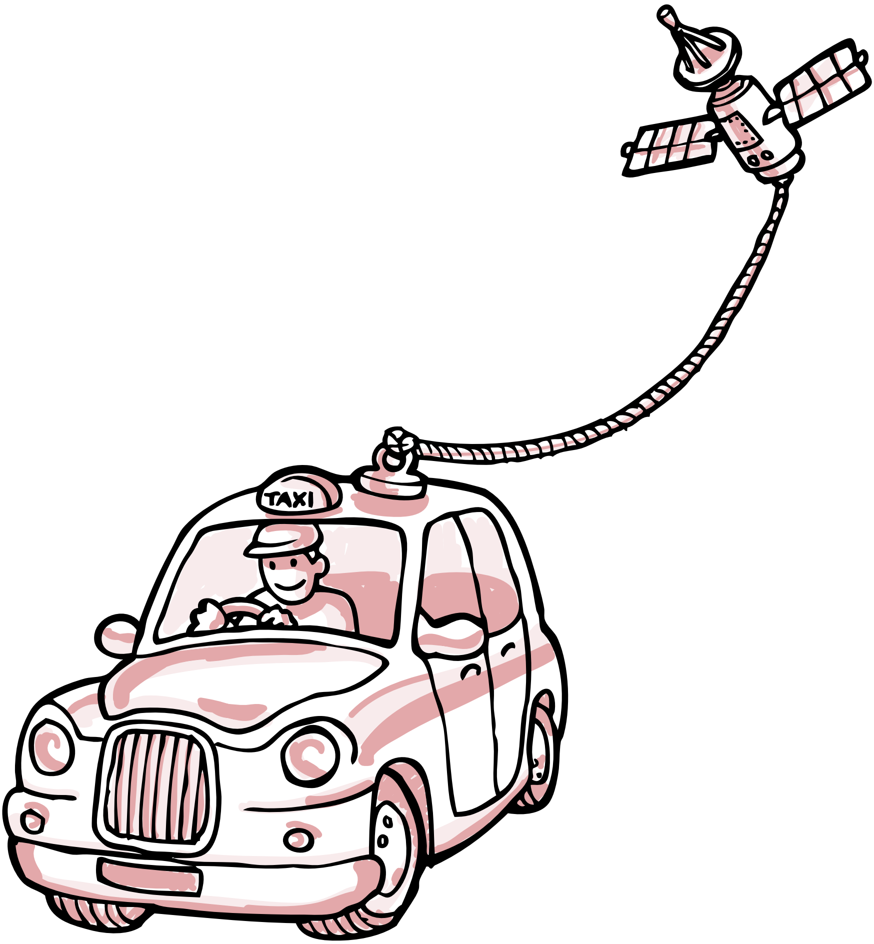
Unlike others, Jennings is confident that a computer could never replace her talent and skills. *"With software you can pick any photograph, distort it and caricature it, but you still have to be a caricaturist to know what to distort, what feature to exaggerate and what expressions to read,"* she said. *"You have to read the face and read the character in order to pull the face in the right direction. This human touch will never be achieved by a computer."*

She added:

> *"Okay, so if you only making someone's ears enormous, like Prince Charles, you can't go wrong, but if people start distorting the face and don't do it correctly in line with the personality then it very, very easily becomes grotesque and inaccurate so you have to be quite a good caricaturist just to do that."*

The experience of Jennings and others, whose jobs are being gradually changed due to IT or bypassed altogether as people are faced with a wholly computerised service, demonstrate mixed feelings towards this change. For some, it is exciting, far more efficient and saves them a lot of time. Others are nervous as they find themselves facing an uncertain future. They are all, however, thoughtful observers of the changes that technology is posing – even where their interests and jobs are being threatened – an image quite different from the political and economic debate that characterises those who oppose technology as modern day Luddites fearful of progress.

But, above all, they tell us that human beings, as it turns out, are not easy to improve upon, as for the time being at least, people want human contact and customers are choosing the checkout worker over the self-service till, the receptionist instead of the touch screen and the cashier ahead of the machine. Can computers beat them? Maybe one day, but I don't think it will be soon.



THE OPTION VALUE OF THE HUMAN

STEVE RANDY WALDMAN

INTRODUCTION

It has become fashionable to worry about the robots. Or 'capital-biased technical change', in the language of economists. What will happen to us, how will we live, how will we organise ourselves if many of our jobs can be better performed by artifacts than by humans? The problem, obviously, is distributional. If all our work is done for us, then in theory, we should be able to live at least as well as we do right now, but in perfect leisure. But for that to happen, we must each be able to lay claim to wealth we have no direct hand in creating, generated by capital that the majority of us do not own.

In what follows, I offer a case grounded in history that is deeply pessimistic. Technological change has never, in practice, been accompanied by universal distribution. It creates specific winners and losers. One might hope that, fairly quickly, innovations would diffuse to the benefit of all. But that does not happen, because exploitation of innovation requires scarce resources as well as non-rival ideas. First-movers deploy new technology in ways that would not be sustainable if deployed universally, but whose reversal would be intolerably painful. They become compelled — by circumstance, not by ill-intention — to defend the new arrangements in ways that must prevent universal access. Durable stratification is the result.

History need not be destiny, however. If future technological innovation is accompanied by institutional innovation that renders benefits broadly shared from the start, then the emergence of defensively hegemonic first-movers could be avoided. One way to accomplish this despite displacement of labour from the production process would be to remunerate people for activities with high 'option value', that is for activities that do not directly contribute to the production of current goods and services but which might prove valuable under various contingencies, ranging from collapse of the automated production process to invention of speculative technologies or authorship of uncertainly valuable cultural artifacts.

CONDEMNED TO REPEAT IT?

The whole robots thing is very glitzy. But this is not a matter of science fiction. Labour–displacing technical change, shocks to the value of a pair of hands, are nothing new in the world. What is new is not what is happening, but whom it is likely to affect.

There is a story that is mostly a lie. That story goes like this. Until the nineteenth century, nearly all of us worked in agriculture. The Industrial Revolution came, tractors displaced most humans, and everybody worried about how they would survive. But, as a fact of nature, labour demand expands to absorb labour supply, and the objective productivity enabled by new technologies meant that the new jobs would for the most part be better and better paying than the old. Perhaps there were some rough transitions, but jobs appeared for the willing hands. Agricultural workers became factory workers, whose capital–augmented productivity translated to high wages and broad–based improvements in the standard of living.

The beginning and the end of that story are all true. In what are now the 'advanced economies', ancient patterns of agricultural production were disrupted, displacing many humans and leaving them worried about how they might survive. Eventually, wealthy, mass–affluent liberal democracies appeared and thrived, for a while. But in between those two events were mass–migrations to cities and across borders; two devastating World Wars (and many smaller conflicts) that significantly curtailed labour supply; unemployment crises, worker unrest, and authoritarian political movements. Successful adaptation, in every developed economy of the mid–twentieth century, was accompanied by the development of welfare states and legally privileged labour unions which 'artificially', from a certain perspective, helped sustain demand for the volcano of consumer products implied by near–full employment of technically–augmented workers.

But at least there was eventual success! Or not. Viewed globally, the outcome of industrial transition looks at best ambivalent. At the beginning of the last millennium, the world was truly flat. There were rich and poor, kings and paupers, everywhere, but the material lives of Africans and Asians and Europeans were not so different. The last few centuries brought the so–called Great Divergence, in which a relatively few countries representing a small share of the global population successfully industrialised while the rest of the world was arguably left worse off, excluded

somehow from the highly-productive employment their empty hands were supposed to compel, dominated instead by foreign powers and domestic elites. In the mendacious telling, each one of these nations had separate histories, and patterns of success and failure are explained by vague factors like 'the quality of institutions'. But in historical fact, there was, shall we say, a great deal of contamination between these experiments. Most of the countries we now view as failures were, during much of the Great Divergence, literally colonies of the successes, and nearly all now trade in global markets. The Industrial Revolution was a global, not a national event, and it had more than its share of losers. If we examine the global experience, we'd find that 'prosperity' as measured by GDP per capita has expanded to some degree nearly everywhere. People everywhere have cellphones. (Hooray.) But it is not at all clear, when social and political factors are taken into account, that the Eurocentric Industrial Revolution was, overall, a positive development for the typical African. And it is indisputably true that the benefits of technological development have been very unequally shared.

So the hazard we now face is nothing new. Over the past few centuries, labour-displacing technology divided the world between communities of insiders that controlled and enjoyed the fruits of enormously productive technology, and outsiders who found themselves with no claim to insiders' wealth. Somehow and somewhat mysteriously, most outsiders were persistently frustrated in their attempts to reproduce the success of early winners, or even to defend prior social arrangements against destabilisation or colonisation in the brave new world that emerged. Now labour-displacing technology threatens to repeat precisely the same trick within the national communities that were the winners of past technological transitions.

ADDICTION THEORY

In a certain sense, the failure of the Industrial Revolution to bring about a broadly shared prosperity is a puzzle. Technological ideas really do cross borders pretty freely, and did so long prior to the internet. Why weren't industrial technologies universally adopted? If it takes less human labour to make more goods and services, why don't we just create so many goods and services that all the labour is still absorbed and we are all phenomenally wealthy? That's (roughly) what happened in the postwar prosperous West. Why didn't it happen everywhere?

The current fashion is to blame 'bad institutions', a phrase so vague as to be indistinguishable from confirmation bias. The losers lost because they had bad institutions, which no true Scotsman would abide. Empirical work on the subject finds that the best operationalisation of 'good institutions' has nothing to do with what most people think of as institutions, but instead measures the degree of sociocultural connectedness with ex post winners, specifically the degree to which colonisers intended to actually live in the countries they now dominated. When colonisers colonised merely to extract, the story goes, they imposed bad institutions. When they planned to reside in the colonies, they erected good ones. But that story invites a more parsimonious account, the

sociocultural winners won and the losers lost, regardless of the geographies they ultimately inhabited. In places where losers mixed with winners, some crumbs fell from the table.

Plus, there is an obvious point that is rarely discussed among polite economists. Given the Earth's resources and technology as it existed in the mid-to-late twentieth century, it would have been physically impossible for the entire world to have enjoyed the standard of living that prevailed in the United States, Western Europe, Australia, and Japan. Three-quarters of the Earth's population were effectively excluded from modernity. For that not to have occurred, we would have required roughly four times the oil, steel, etc., than we actually extracted. It is a mistake to assume, as the 1970s 'limits to growth' movement did, that resource constraints permanently bind. Technologies, of extraction, efficiency, or substitution can and usually do relax them, eventually. But that sort of progress takes time, usually a few human generations, and the mechanism by which it is propelled is high prices. In a counterfactual twentieth century during which industrial development was universally shared, the prosperous West would not so quickly have achieved the standard of living it did achieve. Instead, resource prices would have shot upwards and much more attention would have been devoted much earlier to efficiencies and alternatives that in actual historical fact we are only now beginning to explore.

Technological development is, in econospeak, an asymmetric shock. Somebody does it first. The relatively small community of 'first-movers' enjoy an odd sort of paradise, for a time. They get to implement the possibilities opened up by the new technology under the resource prices that prevail prior to widespread adoption of the invention. 'Rock oil', before kerosene lamps and then internal combustion engines, was a cheap resource whose prevalence or limits were not of great concern. In economies at the technological frontier, internal combustion engines became a centerpiece of industrial development based on prices that could not have survived universal adoption. Lifestyles and habits and long-lived physical infrastructures were transformed based on prices that, from a certain perspective, ought to have been understood as ephemeral and anomalous. In actual fact, low resource prices were not so ephemeral. Petroleum was as cheap in the 1990s as it had been in the 1890s (adjusting for inflation, of course). One response to that, common on the economic right, is to laud markets and human ingenuity. The doomsayers were wrong! Resource scarcities failed to appear because new sources were continually discovered. Unfortunately, in arithmetic terms, the 'decision' by three–quarters of humanity not to industrialise over the period played a much larger role in stabilising oil prices than the recruitment of new oilfields. The process by which oilfields were discovered and brought into production for global markets was a mix of decentralised, emergent market activity and intentional action by governments and large corporations. The process by which most of the world chose not to industrialise was perhaps much the same.

So here is a tragic and sadly realistic account of sociotechnological development: something is invented. 'First–movers' rush in to exploit the invention. In doing so, they become very wealthy. They gain market power (by virtue of superior experience, networks effects, etc.), and political power. The communities in which they reside and the lives of individuals within them are transformed by the new wealth and technology in ways that would be painful to reverse. Without malicious intent, these communities then deploy their wealth, power, and prowess to secure low–cost access to the resources on which they depend, access which in practice would be threatened by universal replication of their own experience. The result is a highly polarised, zero–sum world, in which the prosperity of outsiders must be suppressed if the lifestyles of insiders — now embedded in everything from habits to physical infrastructure — is to be sustained.

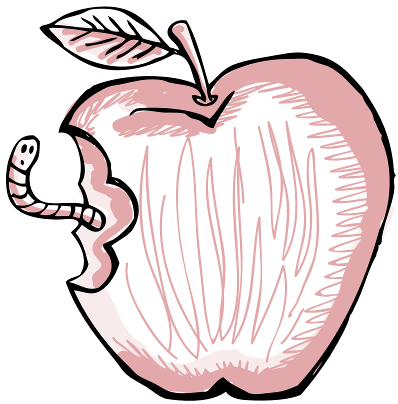
ROBOTS AND RESOURCES

But all of this is ancient history. What does it have to do with the coming of the robots? Everything, I am afraid. The basic dynamic we have described applies to communities smaller than industrialising (or not–industrialising) nations, and it applies in the present as much as in the past. We will not all find ourselves with replicators fulfilling our desires on–demand and robots performing services that we require. Some of us will have these things first. These 'lucky ones' will find they have little use for human labour, but they will still require very many other resources. And they will not feel 'rich'. We never do for very long! Whatever miracles the new machines perform, their lucky owners will rearrange their lives so that those miracles come to seem absolutely indispensable.

They will form communities within which the miracles are commonplace, in which lack of access to such miracles is a kind of pathetic and foreign poverty. We see this now, and we mock it — unfairly — when the odd investment banker explains to *The New York Times* why it is impossible for him to live on less then 500,000 a year. It is not really optional, if you are a managing director at Goldman Sachs, to have an apartment that costs several million dollars and to send your kids to expensive private schools. Or, more accurately, it is optional, in the same sense that having indoor plumbing and electrical power is optional for ordinary Americans. After all, thinking globally, lots of people, perhaps most of the planet, do without!

The fruits of technological change will, as always, be unevenly distributed. The communities that enjoy those fruits first will quickly adjust to them. They will become preconditions of civilised living rather than surplus luxury and wealth. There will be people at the margins of those communities struggling painfully to keep their place, for whom the living, however comfortable by the standards of other communities, will not feel easy at all.

But if the lifestyles enabled by those new technologies are, as they are likely to be, resource intensive, people in these first-mover communities will face strong incentives to restrict access. This will not be a matter of sadism. It will not be an overt, conscious choice. But these communities will be exposed to stress from rising resource prices, and will respond strategically within markets and political systems to protect supply chains upon which they depend. If the robots need molybdenum and molybdenum is scarce, robot-dependent communities will work to ensure exclusive and inexpensive access rather than see prices bid to intolerable heights under universal adoption. Inflation will be the enemy, not other humans, but inflation is what happens when other people have the purchasing power to bid for resources that you yourself desire.



You might argue — you should! — that this theory overpredicts dystopia, and so flies in the face of the basically optimistic experience of the so-called developed world. Why during the twentieth century didn't small communities create and entrench lifestyle differentials for themselves analogous to the lifestyle differentials that persisted between the first world and the third world? How did the period of postwar mass affluence come to exist at all, if the dynamic I describe of addiction and exclusion is real?

History is not a theory. It depends upon its details. It happened to be true that, while the technologies of the Industrial Revolution displaced labour from farms, they also concentrated large numbers of workers into vulnerable factories, creating conditions under which effective labour movements could arise. It happened to be true that, at the level of security technology that prevailed, large numbers of aggrieved individuals could become disruptive in ways that the political system and even the most wealthy communities could not afford to ignore. World War II happened, which disrupted parochial and stratified communities in favor of national communities, and which required soldiers, who were promised claims on future wealth in order to be motivated to fight. Addiction and exclusion define a very real dynamic, but not the only dynamic.

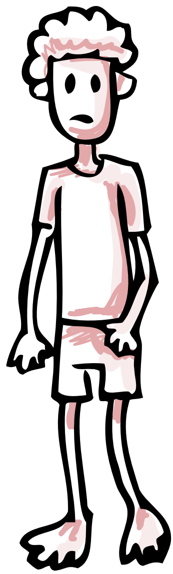
However, an automated factory does not create conditions for an effective labour movement. Technologies of distant violence and social control are much better developed then they were half a century ago. To the degree that technologies of production were complements of human labour, the asymmetry of access to new goods and services was mitigated by the fact that large groups of workers could claim significant shares of what they produced. When technologies are genuine substitutes for labour, much smaller groups might claim their fruits, and then become accustomed to styles of living that would be unsupportable if widely enjoyed. That is the outcome we should fear, and prevent.

SOCIOECONOMIC COHESION

In all of this dreary hypothesising, technology is never really the villain. Technological development, especially labour-displacing technological development, is a good and wonderful and fantastic thing. It makes us richer, it frees our hands from drudgery and toil and affords us possibilities to create in ways that needn't be reduced to commodifiable value. Labour-displacing technology could and ought to be liberating!

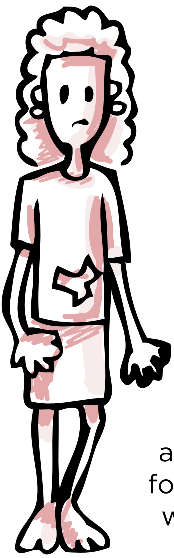
Dystopian outcomes occur by virtue of the asymmetry of access to the fruits of technological development. If industrial development had occurred globally and simultaneously, resource prices would have risen early, and Western standards of living would have risen more slowly. But they would still have risen, as we developed efficiencies and substitutes and more effective extraction techniques. And they would have risen universally, without any need for dirty wars across the world to protect a minority's not–universally–sustainable way of life. It would have been a shame, in its way, if the 'muscle car' era would never have been affordable and so was skipped entirely, if the energy directed towards building powerful V8 engines had instead brought us tiny fuel–efficient hatchbacks two decades earlier, if cities continued of necessity to be designed compactly around good public transport for the many who could not afford to fuel even a Corolla. But it would have been a small price to pay if it meant that Africans, like Americans, would have enjoyed civilised, well–ordered industrial societies.

The key to ensuring positive social outcomes from technological change is to prevent the emergence of powerful communities that get far ahead of the rest of humanity in their enjoyment of and adjustment to technologically created possibilities. This doesn't mean there cannot be wealthy individuals. The hazard comes when socioeconomically distinct, politically potent groups emerge which live very differently from the broader public in ways that require unusual access to scarce resources. It is one thing to be richer or poorer in a basically middle class society. It is quite another thing to fall from civilised society to barbarism, from affluence to underclass. Technological development becomes dangerous when human affairs become segregated and stratified. The answer to the problem of addiction and exclusion is not Luddism, but simply socioeconomic cohesion.



It has become taboo to even discuss socioeconomic cohesion as an object of public policy because we are so far along a different path. In global terms, it is almost impossible to imagine or to advocate a world in which the material possibilities of a typical African or even of a typical Chinese would be comparable to those of a typical German or American. Even within the rarified heights of the developed world, the lifestyles and circumstances of the affluent have increasingly diverged from those of the broad population, and physical and social segregation by affluence has increased. Under these circumstances, technological development really does become something to fear. Technological changes may be asymmetric 'shocks', but their distribution is far from uniform. The technological frontier lives and advances primarily among those who are already advantaged relative to the broad public, who may already have and use disproportionate political power to inhibit inflationary competition for resources on which they depend. The robots (or at least access to the goods and services they produce) will come to America before they come to Africa. They will come to Palo Alto before they come to Detroit. As advanced communities pull further and further ahead, the prospect of a fall becomes more and more terrifying, increasing the willingness and perceived righteousness of insiders' efforts to protect their positions, whatever the costs to outsiders. The prospect of living like a typical American or European may already be as unthinkable to an emerging elite as the prospect of living like a typical African would be to citizens of the developed world.

If that doesn't sound to you like a good world, the only way to prevent it is to take responsibility at a policy level for socioeconomic outcomes to slow or even reverse economic stratification. Labour-displacing technology could be a wonderful thing, if its fruits were broadly shared by a unified human community. But, absent countervailing policy, labour-displacing technology is likely to exclude the vast majority of humans, even within developed world, from sharing in the increased prosperity it could in theory enable. Instead, gains will be concentrated among a small minority whose habits and lifestyles would be threatened by a broader prosperity, and so who somehow contrive to suppress that. If recent history is a guide, most of that suppression won't take the form of overt, outright oppression. Instead, losers will be 'pathologized'. Somehow there will emerge social conditions under which most of the excluded will find themselves unable to succeed despite



ostensibly open neutral contests for access to technological prosperity. It will be their fault. They just won't be good enough. The Nigerians and Namibians have their bad institutions. Now, Charles Murray observes, the once-strong institutions of formerly prosperous middle America are fraying. White working class communities are the new 'tangles of pathology', as Daniel Patrick Moynihan famously described 'negro ghettos' in the middle 1960s. Now as then, insiders will cluck with perfectly good intentions about the 'cultural problems' that plague and condemn the new outsiders. So intractable! And that is why we are 'coming apart'. Or at least, that will be the story.

THE OPTION VALUE OF THE HUMAN

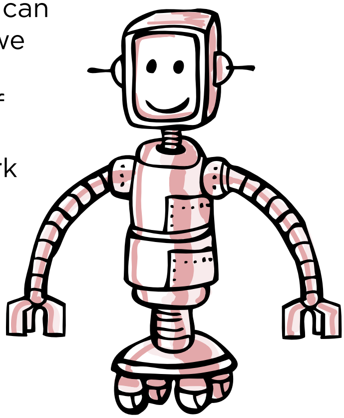
Predictions of dystopia are most useless when they are correct. The purpose of a pessimistic forecast should be to help inspire conditions under which it will be rendered inaccurate. Our initial conditions are not so good. Impossible gulfs remain between 'advanced economies' and much of the world. Analogous gulfs are growing within developed countries between the top of the wealth distribution and erstwhile middle classes. There may be less than meets the eye even to apparent convergences between nations, given the degree of inequality within fast-growing, 'successful' emerging markets. Looking at individuals, a prosperous class that is multicultural and transnational seems to be diverging from everyone else. (There may be some genuine convergences within the international 'everyone else', experienced as upward mobility among workers in emerging markets and stagnation or retrocession among workers in developed economies.)

History is a sunk cost. Divergences, once embedded in habit and infrastructure, usually can't be undone by spreading the static wealth, at least not without destructive, violent conflict. The pain of adjustment is simply intolerable to the dependent, vulnerable 'rich'. It is perceived as an existential threat. If we are to avoid, or more accurately, to remedy, highly-stratified societies, the only practical strategy is to try to direct the fruits of growth disproportionately towards the bottom and middle of the wealth distribution, so that there is upward convergence over time (without requiring complete stagnation for any group). Unfortunately, that has proven difficult to arrange historically. The next wave of labour-displacing technology will make it particularly difficult under present economic institutions, under which the fruits of production are distributed on the basis of labour provided or capital held. Labour providers will be paid less (in aggregate), concentrating the fruits of production among disproportionately wealthy capital holders. If we are to avoid a *Blade Runner*–esque, highly–stratified mass dystopia with well–guarded pockets of elite hyperaffluence, we will need to alter our economic institutions full stop. The fruits of increased production will have to be distributed (in part) on grounds other than capital held or labour provided.

One important possibility is an unconditional basic income, or better yet truly universal cash transfers whereby technologically advanced nations would supply (small) incomes not just to their own citizens, but to every human on the planet whose governments permit it. Universal cash transfers represent a particularly attractive policy. They divert some of the fruits of growth from the top of the global wealth distribution to the very bottom (supporting upward convergence). They also promote employment in the donor country, as the funds exported in donor–country currency must be spent on donor–country goods, or else (if the funds accumulate externally) put downward pressure on the donor country's exchange rate. China's mercantilistic currency management can be understood as a synthetic transfer to Western consumers in support of domestic employment and politically influential exporters. Advanced countries can play that game too, in support of their own social peace and the prosperity of bottom billions. It's a positive sum game, as it addresses objectively unmet material needs of the global poor, while broadening the wealth distribution and offsetting technological disemployment within advanced economies. As the robots come, domestic demand will be increasingly insufficient to generate full employment. So why not import (or really create) global demand? Think of it as an ongoing Marshall Plan, which enabled a devastated Europe to purchase US exports, to the long–term benefit of both. There are still a lot of unmet needs on the planet. Politically, providing very small (by advanced–economy standards) universal incomes intended to help the truly poor in less developed countries may be an easier sell than offering the substantial domestic incomes required to generate the same demand, as sizeable basic income proposals engender resentment of the self–identified industrious toward alleged dependents and scroungers. The transfers could be financed by a variable combination taxes, borrowing, and outright money printing. That would lead to some combination of inflation and increased employment, which is exactly what broad-based growth looks like. Widely distributed purchasing power provokes general price inflation, but prices rise most for goods and services for which there is high demand and/or resource constraints, spurring innovation to produce what the bulk of humanity (rather than an affluent sliver) wants and needs.

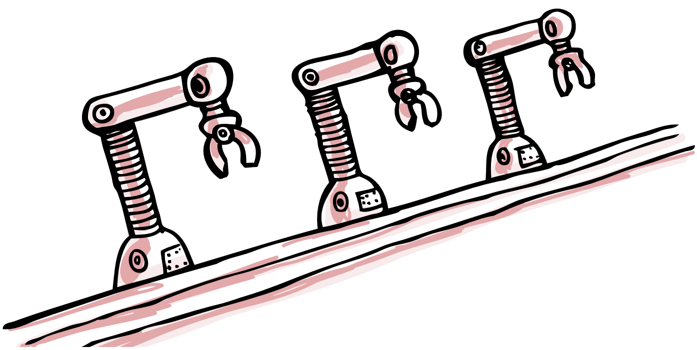
Ultimately, however, labour-displacing technology may advance, especially in tradeable manufactures, to the point where domestic employment cannot be supported by export demand. Pretty soon, to a good first approximation, there will be no one but the robots in factories. Employment, to the degree it is still available at all, will be restricted to services that cannot easily be traded internationally. Domestic transfers will be required at that point, both to engender sufficient demand for employment in services and to provide some support to those who, whether voluntarily or not, will fail to work at all. Those transfers might take the form of labour subsidies or negative income taxes, to help humans compete with the robots by reducing their relative cost to potential employers. They might take the form of an unconditional basic income. They might attach to some evidence of difficult-to-monetise cultural production, or caregiving, or childrearing, or other forms of not-market-regulated yet socially desirable behavior. One way or another, social transfers will have to happen if we wish to prevent a dynamic of divergence, addiction, and exclusion that leads ultimately to a very unpalatable society. But what is the best way to arrange them?

It is worth asking, in a world where robots can do every sort of routine job, what is it that we would want humans to do with their spare time? One answer comes from the theory of financial derivatives. A human being who is not performing immediately productive work is like an out-of-the-money option. Out-of-the-money options are worth nothing at all, pure zilch, if exercised immediately. And yet people are willing to pay a great deal to own them. Their value comes from the possibility that, in an uncertain and ever-changing world, they will somehow



become directly valuable. When we write an option, we enhance its value by increasing the likelihood it will come 'into the money', but also by increasing the payoff it will provide should it do so. Options are most valuable when the world is rapidly changing, which it likely will be even after the robots take our jobs.

As routine work is taken over by robots, we might reconceptualise the economic role of humans as responders to unusual contingencies. We will have expert systems, but we will still want human experts in almost everything (in order to make sense of the expert systems if nothing else). We will need to remember, not just in a bookish sense, but also in a muscle–memory sense, the vast range of human skills that will be rendered uneconomic in mainstream production. So we should subsidise all kinds of craft–y production, from blacksmithing to yarn–spinning to carpentry to unmechanised farming, in case we should someday have use of them. We should run some mid–twentieth century assembly lines and supply chains, which would serve simultaneously as museum pieces, laboratories, universities, and insurance policies. We currently fund academics to invent branches of mathematics for which we have no current use. Given lots of available humans, we should do a lot more of that, and see whether those abstruse new subfields don't turn out to be useful. We should encourage lots of offbeat invention, make laboratories and experts and resources available for people to seriously try, but usually fail, to invent ultracapacitors or cold fusion. We should cede the realm of the ordinary almost entirely to the robots, and try to shape the humans into an outrageously diverse portfolio of options such that in any and every contingency that might arise, we have a wealth of skill and resources to fall back on (and eventually use to build new robots once a former unlikely contingency becomes an ordinary necessity).



Like out-of-the-money options, the typical individual may ex post offer no direct value. But some unpredictable few of these people will turn out to be immensely valuable. We pay for the possibilities they offer, not for the certain, measurable marginal product in old-fashioned labour models.

For the option value they provide, as long as they are active in their own unlikely spheres, we should pay the humans well.

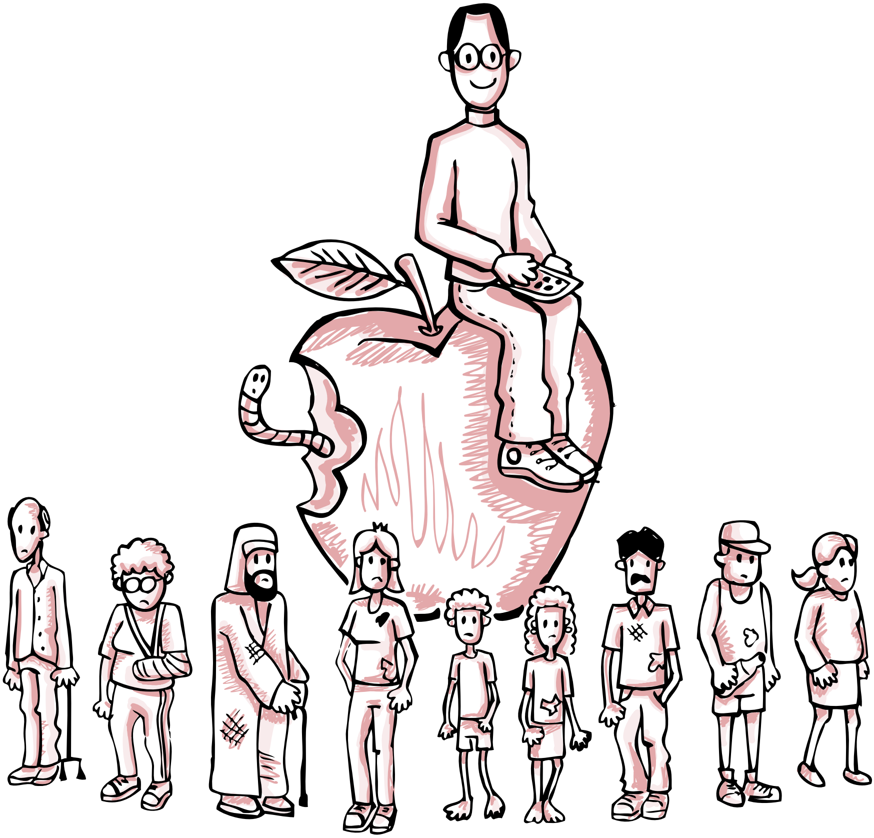
CONCLUSION

Human lifestyles are sticky backward. When a human community experiences technological change or unusual wealth, its habits, institutions, and physical infrastructure typically adjust to the new circumstance such that a reversion to prior ways of living would be catastrophically painful.

Lifestyles carry with them a resource footprint. When a community adjusts to a lifestyle that depends on intensive use of scarce physical resources, continued low-cost access to those resources become an existential requirement. If adoption of a resource-intensive lifestyle is asymmetrical — that is if some small community of 'first-movers' adopts and adjusts to a new lifestyle based on low prices reflecting only their own demand — that community becomes extremely vulnerable to the inflation that would result if the resource-intensive lifestyle were adopted universally. Securing the first mover's supply chain necessarily involves excluding outsiders from successfully replicating insiders' lifestyle change. This circumstance may not be permanent: advances in extraction, efficiency, or substitution may eventually enable expanded access without threat to first-mover lifestyles. But while exclusion prevails, we should expect to observe restrained resource prices alongside communities of people who would like to adopt the resource-intensive lifestyle but somehow find that they cannot.

The Great Divergence between advanced economies and the rest of the world can be attributed to asymmetrical adoption of and adjustment to the technologies of the Industrial Revolution. However, the process is ongoing as some communities within advanced economies become accustomed to yet more resource-costly lifestyles made possible by early access to technology or unusual distributional success. Automation and other labour-displacing technical change threatens to exacerbate this dynamic by expanding resource–intensive production while reducing the number of people capable of laying claim to the output and the price of labour for low–productivity services. If these smaller groups become accustomed to ways of living that could not be universal even within the erstwhile developed world, we should expect the same result as before: a divergence within, restrained resource prices alongside people who would like to adopt more resource–intensive lifestyles but are somehow excluded from participation.

The only remedy for this dynamic is socioeconomic cohesion: not permitting first–movers to become adjusted to lifestyles very far beyond what could be universally supported under present resource–use technologies. Where divergence has already occurred, our best approach is to ensure that the fruits of new technological development and economic growth are directed disproportionately towards permitting those left behind to enjoy better lifestyles rather than to creating new gaps between advanced adopters and excluded outsiders. Obviously, that is all politically challenging. Given that automation is likely to diminish the ability of outsiders to make labour–based claims upon resource–intensive production, we will need to alter the basis on which claims to production are distributed if they are to be distributed more broadly. In addition to traditional social transfers (including basic incomes and truly universal cash grants), I suggest we should reconceptualise what it is that people should be paid for. In addition to compensation for any direct role in production, people should be paid for 'option value', for maintaining diverse skills and expertise and engaging in experimentation that could become valuable under some contingency, even while that contingency is unforeseen.



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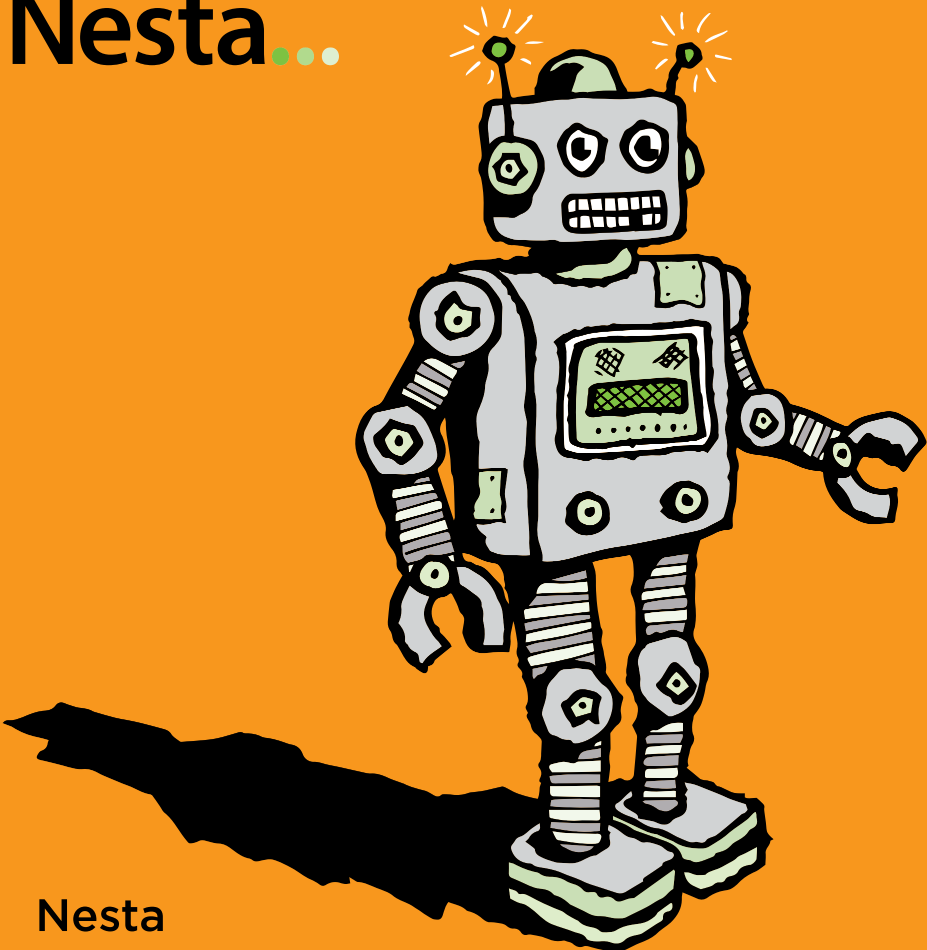

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