The Rise of the **Machines**

preparing for the revolution in robotics and artificial intelligence

research paper and discussion briefing by

Josh Parikh

Jubilee Centre

BIBLICAL THINKING FOR PUBLIC LIFE

Contents

Introduction

In light of the coming revolution in robotics and artificial intelligence, this paper looks to examine some current trends in robotics and artificial intelligence and the social implications of these trends.

The increasing prevalence of news stories on these topics is bringing many of the issues surrounding AI and robotics to the forefront of the public imagination. From the ethics of military drones, to the moral obligations of robots, to AI as a global catastrophic risk (threatening human extinction), there are a number of interesting and important questions arising which require the attention of Christian researchers. Due to limited space, this briefing will focus on two major issues; firstly it will cover key trends in AI development (namely, the speed, scale and potential capabilities of these new technologies) and secondly, the implications of these trends for work, inequality and social isolation. The aim is that this research briefing will provide a helpful starting point for those looking to understand the issue, whilst also prompting further research and discussion from a Christian perspective, in order to better prepare for the changes to come.

It should also be noted that, following the lead of the Parliamentary Robotics and Artificial Intelligence inquiry, I will be using the terms artificial intelligence and robotics reasonably interchangeably in this paper, since there is an 'important degree of interdependency' between the two.[1] A further discussion of the terminology used can be found at the end of this paper.

Trends

1. The speed and scale of AI development

Back in 2004, it was considered that tasks such as driving would be too difficult for machines given the complex spatial awareness, distance estimation and interpretation of different sensory inputs that driverless cars would need to undertake. The conclusion was that computers could not be easily substituted for humans when it came to driving. Indeed, driving might be considered as one of those areas in the sole purview of humans and not vulnerable to automation.[2] And yet in 2010, just six years later, Google made the surprise

[1] UK Parliament, 'Robotics and Artificial Intelligence: Fifth Report of Session 2016-2017', *House of Commons Science and Technology Committee*, 2016 [online], available at: https://publications.parliament.uk/pa/cm201617/cmselect/cmsctech/145/145.pdf [accessed 18 July 2017].

[2] Levy, F., and Murnane, R., *The New Division of Labor: How Computers Are Creating the Next Job Market* (Princeton, NJ: Princeton University Press, 2004).

announcement that their completely autonomous cars had been driving themselves, in traffic, on American roads and highways for some time. The results of these secret tests proved that which was supposedly invulnerable, was much more vulnerable than originally thought.

Similar surprising results were seen in the development of DeepMind's *AlphaGo* robot. Go is an abstract strategy board game, many times more complex than chess, with millions more possible moves. The development of *AlphaGo*, a robot designed to take on world class Go players, was a challenge much harder than chess. In early 2016, Lee Sedol, 18-time world champion of Go, suggested that in competition with *AlphaGo* he thought he would 'win the game by a near landslide'. Despite growing reports of *AlphaGo*'s skills, Sedol continued to believe that he would come out on top, which left him very surprised when he suffered a loss in his first game with the robot. Eventually, he 'kind of felt powerless' against his machine opponent.[3]

These stories are cautionary tales about the speed and scale of AI development. There have been several extraordinary innovations in history, which have been called 'general purpose technologies' (GPTs). These are new ideas or techniques which have impacted widely on many different sectors of society and the economy.[4] Previous examples of GPTs might be electricity or steam power, with the Industrial Revolution stemming out of the invention of the steam engine. It is argued that artificial intelligence is a further GPT, with society-shaking implications.

Artificial intelligence will have society-shaking implications.

A useful guide to this innovation is the rule of thumb known as *Moore's Law*, which suggests that the amount of integrated circuit computing power you could buy for one dollar doubles roughly every 18 months. This means that computing power becomes much more powerful over time, and also much less expensive. This has held up surprisingly strongly over the previous 50 years, and is an exponential increase with great consequences. We are often unable to understand exponential increase, so an analogy is helpful. Suppose you folded a paper in half once, and then you did it again, and then again and over again. By 3 folds you might approach the width of a fingernail; after 7 folds, you approach the width of a notebook. How high would 25 folds in half reach? The answer is it would be over 3km in height. At 30 folds, you reach over 100km

[3] Quotes taken from Bostrom, N., 'Interactions between the Control Problem and the Governance Problem', *Future of Life Institute,* 2017 [online], available at: https://www.youtube.com/watch?v=_H-uxRq2w-c [accessed 18 July 2017].
[4] The definition of GPTs is taken from Erik Brynjolfsson and Andrew McAfee's *The Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies* (New York: W.W. Norton & Company, 2014) which itself builds on the work of economic historian Gavin Wright.

high, reaching into the atmosphere.[5] The massive scale of increase that results from exponential growth can be extraordinarily powerful. Moreover, there is no sign of Moore's Law breaking down anytime soon. In January 2017, Intel CEO Brian Kzanich is quoted as saying: 'I've heard the death of Moore's law more times than anything else in my career ... And I'm here today to really show you and tell you that Moore's Law is alive and well and flourishing.'[6]

2. Greater capabilities

Insofar as computers and robotics become more powerful, they can accomplish more, making a wide variety of human tasks susceptible to replacement by machines. If machines can do a job better and more cheaply than humans, then it is plausible that companies may choose to replace humans with machines. The extent of possible automation is disagreed over, with a variety of estimates suggested by leading authorities. In 2015, a Citi GPS report suggested that 35% of jobs were vulnerable to automation in the UK,[7] whilst the OECD suggested that 9% of jobs would be at risk as an OECD average, with plausibly fewer in the UK.[8] Then again, in 2017, PwC suggested that by 2032, we could see 30% of jobs vulnerable to automation in the UK.[9] Since these estimates clearly differ, and are also subject to a number of caveats (such as the possibility of social resistance to automation and the previous failures of AI predictions),[10] the precise number of jobs is not the most important question to resolve currently. What is important instead is that a wide range of authorities are expecting the vulnerability of large proportions of the workforce to automation.

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[5] I take these numbers from Varghese, R., 'Exponential Growth', 2007 [online], available at: http://raju.varghese.org/articles/powers2.html, [accessed 18 July 2017]. Folding becomes quickly physically impossible.

[6] Quoted in: Pressman, A., 'Here's How Intel is Getting Back on Track With Moore's Law', *Fortune*, 2017 [online], available at: http://fortune.com/2017/01/05/intel-ces-2017-moore-law/ [accessed 18 July 2017].

[7] Frey, C.B., Osborne, M., et al, 'Technology at Work: The Future of Innovation and Employment', *Citi GPS Reports*, 2015 [online], available at: http://www.oxfordmartin.ox.ac.uk/downloads/reports/Citi_GPS_Technology_Work.pdf [accessed 18 July 2017].

[8] Arntz, M., Gregory, T., and Zierahn, U., 'The Risk of Automation in OECD Countries: A Comparative Analysis', *OECD Social, Employment and Migration Working Papers,* 2016 [online], available at: http://www.oecd-ilibrary.org/social-issues-migration-health/the-risk-of-automation-for-jobs-in-oecd-countries_5jlz9h56dvq7-en [accessed 18 July 2017].

[9] 'Up to 30% of existing UK jobs could be impacted by automation by early 2030s, but this should be offset by job gains elsewhere in economy', *PWC*, 2017 [online], available at: https://www.pwc.co.uk/press-room/press-releases/Up-to-30-percent-of-existing-UK-jobs-could-be-impacted-by-automation-by-early-2030s-but-this-should-be-offset-by-job-gains-elsewhere-in-economy.html, [accessed 19 July 2017].

[10] Frey, C.B., and Osborne, M., 'The Future of Jobs: How Susceptible are Jobs to Computerisation?', *Oxford Martin School*, 2013 [online], available at: http://www.oxfordmartin.ox.ac.uk/downloads/academic/future-of-employment.pdf [accessed 18 July 2017].

Which leads us to ask, which jobs might be intrinsically more resistant to automation? It has been argued that jobs might be made less vulnerable if they require either manual dexterity, social intelligence or creativity.[11] It is then surprising to see the advance of artificial intelligence in these areas too. Looking at creativity, for example, AI has been used to write piano music which is indistinguishable to listeners from human composers; to write jokes and perform stand-up comedy; and to write poetry. Even those areas which are supposedly only the remit of humans are becoming ever more competitive.

Countries with ageing populations may come to depend on robot carers.

Moreover, in the social care industry, the human 'care' element is also vulnerable to robotics. Countries such as Japan, with a strongly ageing population, are considering how robots can help them to deal with their demographic changes. Ministry of Trade Official Motoki Korenaga suggested that 'Japan wants to become an advanced country in the area of addressing the ageing society with the use of robots.'[12] It is plausible that such changes could affect the UK, in light of the ever increasing challenges of dealing with an ageing population.

We can then see that widespread societal changes are coming due to technological innovation, which could bring about unprecedented and deep transformation to society.

Social Implications

In light of these changes, we should consider their social implications. In this paper, we will consider three diverse issues: work, inequality and social isolation.

1. Work

In light of the vulnerability of jobs to automation, there is disagreement among authorities about the effect on employment. There have been worries about jobs declining due to technology for a long time, with the great economist John Maynard Keynes declaring in 1930: 'We are being afflicted with a new disease of which some readers may not have heard the name, but of which they will hear a great deal in the years to come—namely, technological unemployment.'[13] Numerous other notable thinkers have made the

[11] Ibid.
[12] Quoted in: Sharkey, A., and Sharkey, N., 'Granny and the Robots: Ethical Issues in Robot Care for the Elderly', *Ethics and Information Technology*, 14.1 (2012), 27-40 (p.29).
[13] Keynes, J.M., 'Economic Possibilities for Our Grandchildren' in *Essays in Persuasion* (London: Palgrave Macmillan, 2010).

same prediction over the 21st Century, from Nobel Prize winning Economist Wassily Leontieff, to economic historian Robert Heilbronner, to economist Ben Seliggman, suggesting that this worry has been widespread and has continually resurfaced.

Despite these worries about the effects of technology, for the most part they have not been realised yet—jobs have increased with new technologies, and for the jobs displaced by new technological advances new compensating jobs were created to offset them. Technology has come in the past and has, for the most part, been labour-augmenting. Employment levels are still extremely high, with UK unemployment at 4.8% today (the lowest level since 1975), even though labour-saving technology has been increasing.[14] This argument from history holds weight with many, suggesting that the lack of much technological unemployment in the 20th century is suggestive for the future. As one commentator claims, 'There are more jobs in the world today than ever before, after hundreds of years of technological innovation and hundreds of years of people predicting the death of work.'[15] So, are these worries overblown?

I would argue that there are a number of reasons to remain concerned in this case. Firstly, arguments from history are not particularly comforting in light of other, more suitable, parallels. Take, for example, the case of horses in light of the rise of the motorcar. Horses had previously weathered earlier technological advances and yet the rise of the motorcar proved fatal to their employment prospects. Secondly, there are reasons to believe that this time is different because, as mentioned previously, robots and AI are simply able to automate many more activities than before. If robots are having this new effect on employment, then history is not comforting.

Thirdly, empirical suggestions are of a technological displacement of jobs due to current technological advancements. It is currently being argued that 6 lines of evidence converge to suggest that automation is having an effect, these include indicators such as the divergence of productivity from wages, a fall in the share of income going to labour vs. capital (which had previously been a consistent relation) and diminishing job creation in economic recoveries.[16] Moreover, in industries such as US manufacturing, where automation has already

[14] Wallace, T., and Chan, S.P., 'UK Unemployment at Lowest Level Since 1975-But Prices Continue to Rise Faster Than Wages', *The Telegraph*, 2017 [online], available at: http://www.telegraph.co.uk/business/2017/05/17/uk-unemployment-lowest-level-since-1975-prices-rise-faster/ [accessed 18 July 2017].
[15] Andreesen, M., 2016, quoted in: Brynjolfsson, E., 'AI and the Economy', *Future of Life Institute*, 2017 [online], available at: https://www.youtube.com/watch?v=juxQKwTmGyo.
[16] Ford, M., *The Rise of the Robots* (London: Oneworld Publications, 2015), Ch.2.

begun, studies have shown 'large and robustly negative effects' of automation on jobs.[17]

Fourthly, previous revolutions like this might actually suggest further technological displacement. Andrew Haldane, Chief Economist for the Bank of England, examined the effect of the Industrial Revolution on workers, and argues that we witnessed a massive change in the labour market between 1700 and 1850, where the share of unskilled UK workers doubled from around 20% to 40% whilst the number of highly-skilled workers increased, resulting in a hollowing out of the labour market—a hollowing out that is being rerun today.[18] This disruption to the labour market is extreme, with losers in the labour market often being distinct from winners. This might be worsened by the continued increase in AI capabilities—the time taken for retraining will be time for AI to develop more and to displace further jobs, causing deeper disruption.

What this means is that we might see a large number of jobs lost across multiple sectors, with a vast increase in people being made 'unemployable for reasons beyond their own control'.[19] Increases in worklessness are therefore likely to bring about great increases in poverty and this is a more pronounced problem for the UK, with a 2011 review of the European relationship between worklessness and poverty suggesting that the UK has an extremely high linkage between the two, compared to its European neighbours.[20] More than this, worklessness is associated with a wide range of ills. Sociologist William Julius Wilson argues, based on previous extensive research, that 'the consequences of high neighbourhood joblessness are more devastating than those of high neighbourhood poverty…. Many of today's problems in the inner-city ghetto—crime, family dissolution, welfare, low levels of social organization and so on—are fundamentally a consequence of the disappearance of work."[21] This suggests deeper problems for any

Unemployment has an adverse effect on human wellbeing and meaning.

[17] Acemoglu, D., and Restrepo, P., 'Robots and Jobs: Evidence From US Labour Markets', *MIT Economics,* 2017 [online], available at: https://economics.mit.edu/files/12763 [accessed 18 July 2017].
[18] Haldane, A., 'Labour's Share', *Bank of England*, 2015 [online], available at: http://www.bankofengland.co.uk/publications/Documents/speeches/2015/speech864.pdf, p.9.
[19] CGP Grey, 'Humans Need Not Apply', 2014 [online], available at: https://www.youtube.com/watch?v=7Pq-S557XQU [accessed 1 January 2018].
[20] De Graaf-Zijl, M., and Nolan, B., 'Household Joblessness and Its Impact on Poverty and Deprivation in Europe', *Gini Discussion Paper 5*, 2011 [online], available at: http://www.gini-research.org/system/uploads/240/original/DP_5.pdf?1298997991 [accessed 18 July 2017].
[21] Wilson, W.J., *When Work Disappears: The World of the New Urban Poor* (New York: Vintage, 1997) quoted in: Brynjolfsson and McAfee, *The Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies* (New York: W.W. Norton & Company, 2014).

wider response to this problem—it is not sufficient merely to deal with the loss of income that any may face; rather there is a large problem associated with the loss of work alone on wellbeing and meaning.

A final implication might be increasing social and political unrest. It has been argued that labour has fuelled severe political unrest in the past, from which it is suggested that one could attribute the recent election of Donald Trump to widespread automation in the USA—an argument supported by recent analysis of key voter districts in the 2016 presidential election.[22] It can be argued that further political unrest is possible and likely in light of the robotics revolution, suggesting a deep problem which the revolution might cause.

2. Inequality and growth

There is a mixture of excitement and nervousness among many about the coming technological changes. One report from PwC suggests that AI could add $16trn to the world economy by 2030.[23] With such economic growth, one might think that the robotics revolution will be extraordinarily beneficial to the human species. Why then is there great concern about this impending social change?

The answer is that GDP estimates are a greatly imperfect measure of the health of an economy and a society, with numerous prominent economists such as Nobel Prize Winner Joseph Stiglitz, IMF Chairwoman Christine Lagarde, and Erik Brynjolfsson being strongly critical of the focus on GDP growth. One relevant reason to regard this as an inappropriate and ineffective measure of societal development would be its inability to measure the overall distribution of income, regardless of the overall growth of income.

There are good reasons to think the robotics revolution is likely to increase inequality. For one, many argue that inequality has increased over the past 30 years due to technological change—current trends suggest a 'Great Decoupling' of wages from productivity.[24] This would mean that even though productivity has been vastly increasing, it has not been benefitting the wider populace. Moreover, taking into account the arguments put forward in Thomas Piketty's *Capital in the 21st Century* (2013), inequality is to be seen as a natural result of the growth of capital—the rate of return on capital exceeds the rate of growth in any developed countries, and so it naturally follows that the

[22] Frey, C.B., Berger, T., and Chen, C., 'Political Machinery: Automation Anxiety and the 2016 Presidential Election', *Oxford Martin Programme on Technology and Employment*, 2017.
[23] Chainey, R., 'The Global Economy will be $16 trillion larger by 2030 thanks to AI', *World Economic Forum*, 2017 [online], available at: https://www.weforum.org/agenda/2017/06/the-global-economy-will-be-14-bigger-in-2030-because-of-ai/ [Accessed 18 July 2017].
[24] See, Brynjolfsson, 'AI and the Economy' and Ford, *The Rise of the Robots*.

capital owners, who tend to be the top 1% in any countries, have become richer and richer. Here, the role of the super-rich as owners of major companies is also important—many prominent voices on artificial intelligence from Elon Musk to Mark Zuckerberg are billionaire owners of major companies; and 7 out of 10 of the world's richest corporations are investing heavily in artificial intelligence, especially Facebook and Google.[25] This could plausibly increase inequality greatly, if the proceeds of artificial intelligence are concentrated in the hands of owners, or their companies which either pay a few employees well or many employees poorly. Indeed, in Oxfam's 2017 report on the growth of inequality, it found that eight men owned the same wealth as the 3.6 billion people who are the poorest 50% of the world population.[26]

The WEF considers inequality the greatest societal concern in the robotics revolution.

Though caring about inequality growth is sometimes cast as a politics of envy, the consequences of inequality are severe and the founder of the World Economic Forum considers this 'the greatest societal concern' of the robotics revolution. [27] Firstly, there are linkages between inequality and poverty, suggesting that gains to the top of the economy might result in increased poverty at the bottom of the economy. Looking at the work of Abigail McKnight, she summarises a number of links between inequality and poverty, from political mechanisms where rich elites might skew democracy in their favour, to economic mechanisms operating through the labour market, such as the skill-based technological change suggested earlier. This means that an increase in inequality might well cause even greater destitution for those at the bottom.

Secondly, inequality might undermine solidarity between rich and poor. Indeed, inequality is 'corrosive to civic virtue' since it ensures that the rich and poor lead increasingly separate lives, resulting both in a poorer quality of public services, which exist mainly for the poor, and weaker relationships between different classes, which could conceivably lead to increased social tensions.[28] Thirdly, inequality is

[25] Anthonsen, H.S., 'What Powerful CEOs Think About AI', *Access AI*, 2016 [online], available at: http://www.access-ai.com/blogs/what-powerful-ceos-think-about-ai/ [accessed 18 July 2017].
[26] Oxfam, 'Just 8 men Own Same Wealth as Half the World', [online], Available at: https://www.oxfam.org/en/pressroom/pressreleases/2017-01-16/just-8-men-own-same-wealth-half-world, [Accessed 18 July 2017].
[27] Schwab, K., 'The Fourth Industrial Revolution: What It Means, How to Respond', *World Economic Forum*, 2016 [online], available at: https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/ [accessed 2 January 2018].
[28] Sandel, M., *Justice: What's the Right Thing to Do?* (London: Penguin Books, 2009), p.267.

associated with a wide range of further societal ills, from mental health prevalence to incarceration rates to obesity.[29]

As a result, the rise of inequality predicted by the robotics and AI revolution is a strong concern.

3. Social isolation

The final effect to consider is the role of robots in social relationships. This worry is a deep one in light of social robots, who might become more prominent due to pressure on health and social care. In caring for an ageing population, many countries are facing a healthcare crisis, with fewer workers to care for an increasing number of older persons. This results in an expensive healthcare system in order to care for these older people, making automation attractive. There are three 'roles' for robots which have been suggested: (i) 'to assist the elderly, and/or their carers in daily tasks; (ii) to help monitor their behaviour and health; and (iii) to provide companionship.'[30] The introduction of robot workers is therefore likely to transform the social care industry.

This will probably deepen social isolation, for a number of reasons. Firstly, many routine jobs which might be automated away are often a crucial source of interaction for the elderly—with cleaners or housekeeping assistance providing companionship which 'is equally, or even more, important than the actual duties performed'.[31] Secondly, the pressures which are pushing for the automation of jobs in the healthcare industry are not likely to lead to greater interaction. One is the pressure of cost-cutting, as considered by Robert Sparrow, who argues that healthcare dominated by robotics would be a 'dystopia'.[32] Another problem is the way in which robots are designed, which is often neither user-centric, nor based on the needs of older persons, but instead driven by commercial pressures to increase demand—meaning that the needs for social interaction might not be the first priority of robot designers.[33] These problems might mean much greater social isolation is plausible.

Relationships are inordinately important generally and particularly so in this context. Evidence suggests that relationships are vital for the

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[29] Wilkinson, R., and Pickett, K., *The Spirit Level: Why Equality is Better for Everyone* (London: Penguin Books, 2010).
[30] Sharkey, A, and Sharkey, N., 'Granny and the Robots: Ethical Issues in Robot Care for the Elderly', *Ethics and Information Technology*, 14.1 (2012), 27-40 (p.29).
[31] Sparrow, L. and Sparrow, R., 'In the Hands of Machines? The Future of Aged Care', *Minds and Machines,* Vol.16 (2006), 141-161 (p.151).
[32] Sparrow, R., 'Robots in Aged Care: A Dystopian Future', *AI and Society* (2015).
[33] Vincze, M., Weiss, A., Lammer, L., Huber, A and Gatterer, G., 'On the Discrepancy between Present Service Robots and Older Persons' Needs', 2015 [online], available at: http://hobbit.acin.tuwien.ac.at/publications/hobbit_roman.pdf [accessed 19 July 2017].

older population, contributing to increased wellbeing and perhaps even lower mortality risk.[34] Insofar as social robots spur social isolation among the aged population, this is a worrying trend.

Conversely, social robots could also increase social cohesion. One interesting example is the role of robots as social facilitators, acting to enhance human relationships. One positive story concerns an elderly woman aided by a robotic seal toy: 'One 75 year old female resident greatly increased her interaction with fellow residents. A friend of hers commented that she had been taciturn before Paro[the robot toy]'s arrival, but that now she was more cheerful and talkative.'[35] This brings complexity into the analysis of social robots.

Are these human-robot relationships appropriate?

There are also difficult questions for the ethics of human-robot relationships. It is widely agreed that these relationships are a one-way street between humans and robots. Nonetheless, humans are prone to form emotional bonds with robots based upon the smallest of triggers—whether it is the movement of these robots, or their humanoid or anthropomorphic features.[36] Furthermore, this is not an isolated phenomenon, but one that is backed up by numerous anecdotes and studies, and found even in unlikely candidates such as AI researchers.[37]

These 'unidirectional emotional bonds' are unlikely to be intrinsically wrong—we are not worried by children forming an emotional bond to their teddy bears, for example. [38] But there are more troubling consequences for robotics. For one, they might promote irrational decision-making: such as the story of a commander who calls off a landmine robot because the treatment was 'inhumane'.[39] These robots also might be deceptive or manipulative, and it might be disrespectful to substitute these one-directional relationships for others, even if they appear to be equally psychologically satisfying to the participant.[40]

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[34] Sharkey, A, and Sharkey, N., 'Granny and the Robots: Ethical Issues in Robot Care for the Elderly', *Ethics and Information Technology*, 14.1 (2012), 27-40 (p.29).
[35] Ibid.
[36] Lin, P., 'Relationships with Robots: Good or Bad for Humans', *Forbes*, 2016 [online], available at: https://www.forbes.com/sites/patricklin/2016/02/01/relationships-with-robots-good-or-bad-for-humans/#11f713ae7adc, [accessed 19 July 2017].
[37] Scheutz, M., 'The Inherent Dangers of Unidirectional Emotional Bonds between Humans and Social Robots', in: eds. Lin., P., Abney, K., and Bekey, G., *Robot Ethics*, (Harvard, MA: MIT Press, 2011).
[38] Ibid.
[39] Ibid.
[40] Sparrow, L. and Sparrow, R., 'In the Hands of Machines? The Future of Aged Care', *Minds and Machines,* Vol.16 (2006).

Conclusion

This paper has given an overview of some of the main literature around these specific AI and robotics issues. It should be evident from this that although the exact timing and extent of a future revolution is not clear, there is a strong consensus that AI and robotics will have a profound effect socially. Moreover, responses to these issues made 'after the fact' will quickly fall behind in the face of the sheer speed and scale of development. Therefore, it is necessary to begin the work of thinking and preparing ahead of time.

Appendix: Definitions

What exactly is meant by artificial intelligence and robotics? Definition of these concepts is extremely difficult. Roboticists themselves struggle to pin down the definition of their field, whilst our own cognitive biases afflict our understanding of intelligence, so that we tend to think of intelligence as thinking only, and of superintelligent beings as like a 'very clever but very nerdy human being.'[41] To do so is to miss out the realms of emotional or social intelligence and spiritual wisdom, for example.

In light of these difficulties, the following working definitions of intelligence, artificial intelligence and robotics are helpful:

I will take, as a starting point, Stuart Russell's definition of intelligence as the 'ability to act successfully,' with Russell arguing that adaptability and strong abstract reasoning are intelligence insofar as they are instrumental to being able to act successfully.[42] I think this is a good definition, but should also account for the nature of intelligence not as a singular ability, but moreover as a collection of abilities, and possessing one form of intelligence might not mean you possess others. With a nerdy professor, one can be a genius at maths, but possess few social skills. In light of this, we might best conceive of intelligence as a spectrum, with beings possessing greater and greater intelligence as having more and more abilities to act successfully, across numerous areas.

Artificial intelligence (or AI), as its name implies, brings together the artificial with the intelligent. In some definitions, artificial intelligence is defined as the study or making of these intelligent machines. I would distinguish the study of artificial intelligence from artificial intelligence itself, as many definitions fail to do—artificial intelligence

[41] Bostrom, N., *Superintelligence: Paths, Dangers, Strategies*, (Oxford: Oxford University Press, 2014), p.111.
[42] Russell, S., 'Defining Intelligence', *EDGE*, 2017 [online], available at: https://www.edge.org/conversation/stuart_russell-defining-intelligence [accessed 18 July 2017].

is discussed widely in business, political and other contexts, and is not only related to an academic discipline. Thus, it is reasonable to suggest that artificial intelligence is high-level intelligence possessed by machines.

Robotics is best defined, as John Jordan suggests after a lengthy discussion of different definitions, as the following, drawing on roboticist George Bekey: 'A robot [is] a machine that senses, thinks and acts. Thus a robot must possess sensors, processing ability that emulates some aspects of cognition, and actuators.'[43]

Nonetheless, it is also true that there is an 'important degree of interdependency' between artificial intelligence and robotics, and it is sometimes difficult to distinguish between the two, as suggested by the Parliamentary Robotics and Artificial Intelligence Inquiry. [44] For this reason, the two shall be used reasonably interchangeably and alongside each other, just as is done by that inquiry.

[43] Jordan, J., *Robots* (Cambridge, Massachusetts; MIT Press, 2016), p.27.
[44] UK Parliament, 'Robotics and Artificial Intelligence: Fifth Report of Session 2016-2017', *House of Commons Science and Technology Committee*, 2016 [online], available at: https://publications.parliament.uk/pa/cm201617/cmselect/cmsctech/145/145.pdf [accessed 18 July 2017].