



# Automation and Collaborative Robotics

A Guide to the Future of Work

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Peter Matthews  
Steven Greenspan, PhD

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Printed on acid-free paper

*This book is dedicated to my wife Pat and  
my daughter Georgina, hoping that their future is  
positive and fun.*

—PM

*This book is dedicated to my wife Wendy,  
my children Hannah and Jonathan, and my grandchildren.  
May they enjoy a world filled with joy and, in the spirit of  
this book, diverse wisdom and intelligence.*

—SG

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# About the Authors



**Peter Matthews**, based in the UK, is a writer and research scientist. Peter has more than 40 years of IT experience ranging from mainframe/Unix programming, development and relational databases to secure cloud computing, DevOps and cobotics. Peter’s research work has been concerned with leading edge technology for a major proportion of that time. Projects have included machine

learning algorithms for soccer clubs, multi-level secure database systems and object-oriented application infrastructures. He has also led groups investigating the influence of macro social, political and economic trends on future technology.

Peter’s current research is focused on automation and robotics. Past research has covered Internet of Things, cloud computing, data curation, smart buildings and cobotics. Peter has been the CA project lead on cobotics under the auspices of the Centre for Visual and Decision Informatics, a USA National Science Foundation initiative.

Peter has authored and co-authored academic papers including “Data Is the New Currency” in the proceedings of New Security Paradigms Workshop. Other writing includes books on “Ingres Visual Programming”, co-authoring of “The Innovative CIO: How IT Leaders Can Drive Business Innovation” and co-editor/contributor to “MOdel-Driven Approach for design and execution of applications on multiple Clouds”.

## ABOUT THE AUTHORS



**Steven Greenspan, PhD** is an innovator of information and communications technology (ICT), with over 50 publications in peer-reviewed journals and 79 US patents, including the first patent to describe two-factor and two-device authentication and authorization. This invention is widely used throughout the world to ensure secure access to web services and it showcased the value of keeping the human-in-the-loop. His current research

interests include user experience and collaboration in complex systems, differential privacy, ethical decision-making, and innovative approaches for integrating scientific research into socially responsible applications and services. Outside of his professional work, he devotes much of his time to community groups that focus on environmental, economic and social justice. He also serves on the advisory boards of the AABGU/ Philadelphia Academic Bridge, and several startups.

Steve has a PhD in Cognitive Psychology from the State University of New York at Buffalo and conducted postdoctoral research at the University of California at San Diego and Indiana University. During the writing of this book, he was a Visiting Scholar at the University of Virginia. Previously, he was a Research Scientist and Vice President of Strategic Research at CA Technologies managing an international team of information technology scientists. He has also consulted to Avaya on the UX design of mobile phones, and was a Distinguished Member of the Technical Staff at AT&T Bell Laboratories.

# About the Technical Reviewer

**George Watt** became passionate about technology and innovation at a very early age and built his first “computer” out of cardboard boxes somewhere around age 5. George led the design workshops for the accelerator program described in this book and created and deployed its foundation artifacts and ceremonies. Throughout his career, George has delivered innovations of his own, such as a knowledge base for a neural network-based predictive performance management solution, one of the earliest private clouds (2005), and a lightweight event management agent. A transformative leader, George has spearheaded initiatives that have enabled organizations to address complex technology problems, deliver new business benefits, and drive millions of dollars in savings and productivity gains. George began his technical career as a systems programmer/sysadmin and systems engineer. He has held many national and global leadership positions and has led global teams spanning North America, Europe, Asia, and Australia. George is co-author of *The Innovative CIO* (Apress, 2012) and *Lean Entrepreneurship* (Apress, 2019) and tweets @GeorgeDWatt.

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First, as always, I would like to thank my wife Pat and my daughter Georgina for their patience and help. They have put up with my incessant questions as well as keeping on top of the catering. Their help has been invaluable; without it this book would not have seen the light of day.

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I would also like to thank Steve Greenspan, my co-author, who has as always given new perspectives in any discussion. It has been great working with him and finally getting this book ready.

—PM

Writing a book is a long journey filled with frustration and joy, confusion and insight. I am thankful to my wife and family for their encouragement and support. Every day, they bring joy. I am especially grateful to my wife, Wendy, and son, Jonathan, who read through one or more chapters and provided me with provocative questions, suggestions, and wise judgment. Rodney Wallace, an economist and author of the book

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—SG

We acknowledge the encouragement and feedback we received from George Watt, our former manager at CA Technologies. He was a very thorough technical reviewer, and the book is much better for his questions, insights, and suggestions.

We also acknowledge the contribution of Maria Velez-Rojas who led many of the discussions on data and visualization and shared her expertise but for personal reasons was not able to contribute as a co-author.

Lastly, we thank Rita Fernando Kim for her patience, sage advice, and keeping us on track. We also thank Susan McDermott and the Apress team for their patience and guidance.

—PM and SG

# Introduction: Toward Utopia, but Slowly

Obeying the orders of “General Ludd” was an excuse used by skilled weavers and textile workers in the United Kingdom whose livelihood was threatened by new weaving machines and practices. Known as Luddites, they smashed looms and factories in an effort to convince the UK Government to deny the march of progress and ban the new machinery. Luddite is used as a term for someone who is afraid of new technology. Automation and robotics are a stimulus driving an increase in the number of modern Luddites.

It is an undeniable fact that automation and robotics, along with their various manifestations, are anticipated to have an impact on society and each individual’s life and work. This impact is potentially far greater than that of the weaving machines and new practices affecting the historical Luddites. Countering a Luddite tendency is not easy with a great deal of negative reporting and scaremongering fueling anxiety, but it is considered best left to education. It is true that jobs being replaced by machines will generate a visceral reaction in many people.

Barely a week goes by without some form of media proclaiming “Nearly 9 million British jobs could be lost to AI by 2030,”<sup>1</sup> “Robots are taking your Jobs!”, or “What Will Our Society Look Like When Artificial

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<sup>1</sup>Kate Ferguson, “Rise of the robots: Nearly 9 million British jobs could be lost to AI by 2030 with workers in retail, manufacturing and business administration most at risk,” Daily Mail Online, January 6, 2019, [www.dailymail.co.uk/news/article-6536065/Nearly-9-million-British-jobs-lost-AI-2030.html](http://www.dailymail.co.uk/news/article-6536065/Nearly-9-million-British-jobs-lost-AI-2030.html)

## INTRODUCTION: TOWARD UTOPIA, BUT SLOWLY

Intelligence Is Everywhere?”<sup>2</sup> It is clear that there is a good deal of concern, further fed by movies and TV shows that show humanity under threat from increasingly dominant machines.

Science fiction in entertainment and literature particularly has embraced this paradigm and has unwittingly (or not) fed this paranoia. Paranoia directed at robots started early with the first use of the term robot, made in 1921 in Czech playwright Karel Čapek’s RUR, or Rossum’s Universal Robots, in English. The robots in this play are not robots in a strict sense; actually they are more like a cyborg, a human/robot combination. The robots become part of a rebellion that extinguishes humanity. The theme of destruction of humanity has continued in disaster and horror genres and is still influencing the attitudes of the public at large.

Recent massive improvements in technologies in both hardware and software have led to improvements in automation and robotics.<sup>3</sup> A Robot Operating System (ROS), improved sensors and encoders are all core technologies for robotics. AI can be considered one of the enabling technologies of automation and decision-making. Hardware improvements with smaller faster chips, graphical processing units, and better power consumption are among other technologies that are making advances in robotics faster. These are leading to an increasing impact on current tasks and working practices. The increasing use of software and physical robots on existing workloads is already creating an impact. Software and physical robots can affect how people are going to be remunerated in the future and decrease the numbers of knowledge workers employed.

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<sup>2</sup>Stephan Talty, “What Will Our Society Look Like When Artificial Intelligence Is Everywhere?”, Smithsonian Magazine, April 2018, [www.smithsonianmag.com/innovation/artificial-intelligence-future-scenarios-180968403/](http://www.smithsonianmag.com/innovation/artificial-intelligence-future-scenarios-180968403/)

<sup>3</sup>Nichols, G. “A robot revolution is well underway, driven by core technologies,” ZDNet, April 8, 2020, [www.zdnet.com/article/a-robot-revolution-is-well-underway-driven-by-core-technologies/](http://www.zdnet.com/article/a-robot-revolution-is-well-underway-driven-by-core-technologies/)

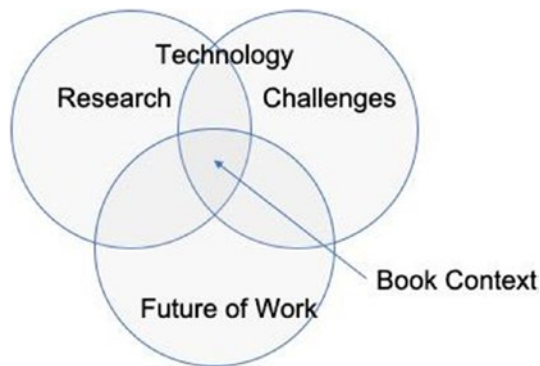
Concern over the vulnerability of jobs to computer-based automation, including robotics, has been expressed since the early days when industrial robots displaced production line workers in automotive plants and software automation displaced routine ledger management. The level of concern has increased with the growth of machine learning and the ability of AI tools to handle more complex tasks.

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This book will approach the issue of automation, collaborative robotics, and their relationship to the future of work by outlining the still considerable technology issues that are faced by designers and developers today.

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The impact of new technology on work is assessed as an overlap between the anticipated changes to work and society, the technology challenges, and the technology research, as illustrated in Figure 1.



**Figure 1.** *Context of this book*

## INTRODUCTION: TOWARD UTOPIA, BUT SLOWLY

The first part of the book, “Preparing for the Future of Work,” describes the social, political, and economic context of the future of work. In it we will introduce automation and robotics as technologies and AI as an enabling technology. This section also includes a number of definitions and descriptions to clarify terms used throughout the book.

The second part, “Robots Are Working,” describes how robots are working today and how they interact with humans. This section includes a discussion on the value of robotic process automation that is currently being realized by organizations who are already using these software robots to good effect. There is also a discussion on collaboration between robots as well as a section that looks at smart buildings and autonomous vehicles.

The final part, “Making Sense for Robots and Society,” exposes two main domains that can potentially advance or derail the value of automation and collaborative robots in the future. The first domain, data fusion, is an essential technique for helping robots to make sense of all the data that is available, including data that has no predefined data model or is not organized in a predefined way. This is called unstructured data and we will show the importance of merging this unstructured data, such as video and audio data, into a view of the operating environment that includes structured data in tables, data streams, and databases. The second domain, policy matters and regulation, is discussed in relation to concerns about uncontrolled or faulty systems and environments. Regulations and monitoring compliance to those regulations are in their infancy in robotics, machine learning, and software robotics. Interest in this area is also being fueled by the scare stories mentioned earlier.

In addition to dividing the book into three major sections, the book contains two perspectives reflecting the experience and judgment of the two authors. One perspective focuses primarily on the technological challenges confronting robotic and process automation. How can work be restructured to take advantage of the latest advances in robotics and automation? What are current limits of the technology, and, how do we work around these? What applications are most likely to benefit

from recent advances in robotics, and how do different applications work together in a technology solution? These questions reflect the background and interests of Peter, who has been involved in machine learning and software robotics since the late 1990s. Peter’s extensive experience in database integrity, information systems management, and decision support informed Chapters 2, 3, 5, and 6 (“Technology Definitions,” “Robotics Process Automation,” “Robots Without Arms,” and “Robots in a World of Data”).

The other perspective concentrates on the impact of robots on organizations and on the regulation of work. How is corporate decision-making and organizational structure affected by the adoption of robots and automation? What new skills will be needed to compete, in a world of humans and collaborative robots? What capabilities will robots need to acquire to be collaborative and productive in a team? What are the obligations and responsibilities of companies that manufacture and employ robots, and how can they work with policymakers to create a sustainable, healthy society? These questions reflect Steve’s experience in cognitive and organizational psychology, and user experience design. Steve’s research in privacy, information technology, and trust underlie the perspective taken in Chapters 1, 4, and 7 (“Will Robots Replace You?,” “Robots in Teams,” and “Robots in Society”).

These two perspectives allowed us to examine the relationship between robots and automation technology on the one hand, and business processes and organization on the other hand.

## **What Is Different About This Book?**

There are many other books and articles that discuss the future of work, from a social, economic, and political point of view. This book takes a different approach—focusing on the relationship between technology, research, and preparing for the future of work. The authors’ background

## INTRODUCTION: TOWARD UTOPIA, BUT SLOWLY

in scientific research, working with leading universities and research institutes, gives them a strong insight to the status and progress of fundamental research into evolving automation and robotics spaces. Their research into cloud computing, AI, enterprise automation, risk management, and decision-making enables them to participate in a number of significant research projects. Collaborative robotics, data fusion, smart buildings, and edge of the network management have been the latest research they have engaged in and gave the impetus to writing this book. Many of the research challenges discussed are just in the early stages of being addressed.

To validate the research discussion, we will use interviews and discussions with leading scientific researchers. These researchers are leaders in their field and they will describe the status of their research and their interest and the future goals for that research.

The way that humans and robots interact is important in understanding collaborative robots and automation in general. We will explore how humans collaborate with robots, how robots collaborate with other robots, and how they work in a team. This is set in the context of the future of work.

The scope of the book does not include industrial robots and their effect on a production line and its workers as we do not believe that industrial robots that carry out repetitive tasks will change significantly while collaborative robots and their relationship to human collaborators will continue to evolve over many years.

## Future of Work

We have already mentioned the hype in the general media as well as the more specialist media. This does not cover the full gamut of speculation although it does color the view of the general public. Business and academic writers, analysts, and researchers are also speculating about the impact on the working population. We are not planning to

exercise a crystal ball and predict the future in the same way that more sensationalist writers are doing, but we can extrapolate from current facts and new scientific research and draw conclusions from these regarding the impact of automation and collaborative robots on jobs and society. There are some writers who have interesting views on this impact. In his 2018 article “What Will Our Society Look Like When Artificial Intelligence Is Everywhere?”<sup>4</sup> Stephan Talty of the *Smithsonian* magazine speculates that AI is already being used increasingly in business. This is supported by a number of reports from university and analyst groups and a forecast from Statista. This forecast predicts that the global AI software market is expected to grow 154% by 2025 and reach a size of 22.6 billion US dollars.<sup>5</sup>

An early examination of the future of work will give context to discussions regarding the research and technology. We will take a journey from our initial views of the future of work through the research and technology and finish with a view of the place of robots in society. Technical terms and research practices may be difficult to read but we will be simplifying and clarifying these terms as we progress. When it comes to economics, we will leave this to Martin Ford who does an excellent job of examining the rise of the robots and the economic impact.<sup>6</sup>

Politicians may have the unenviable task of preparing the working population for massive changes both in the opportunity for employment and the financial impact of jobs being automated. There are many suggestions from changing the way a family can generate an income by

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<sup>4</sup>Stephan Talty, “What Will Our Society Look Like When Artificial Intelligence Is Everywhere?”, *Smithsonian Magazine*, April 2018, [www.smithsonianmag.com/innovation/artificial-intelligence-future-scenarios-180968403/](http://www.smithsonianmag.com/innovation/artificial-intelligence-future-scenarios-180968403/)

<sup>5</sup>Liu, S. (2020, April 8). Artificial intelligence software market growth forecast worldwide 2019-2025. Retrieved April 8, 2020, from [www.statista.com/statistics/607960/worldwide-artificial-intelligence-market-growth/](http://www.statista.com/statistics/607960/worldwide-artificial-intelligence-market-growth/)

<sup>6</sup>Ford, M. (2015). *Rise of the Robots*. Retrieved April 8, 2020, from [www.uc.pt/feuc/citcoimbra/Martin\\_Ford-Rise\\_of\\_the\\_Robots](http://www.uc.pt/feuc/citcoimbra/Martin_Ford-Rise_of_the_Robots)

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aggregating their own data and sell access instead of meekly waiting for the data aggregators.<sup>7</sup> Other suggestions include a universal living wage. What is clear is that society will have to accommodate employment changes and impact that will be every bit as disruptive as the “looms” that the Luddites tried to ban.

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<sup>7</sup>Data as the new currency: In *Proceedings of the 2014 New Security Paradigms Workshop*. ACM.

# **PART I**

# **Preparing for the Future of Work**

## CHAPTER 1

# Will Robots Replace You?

At the dawn of civilization, in the forests of Siberia, a small tribe was engaged in discussion of great importance to themselves and mankind. It was winter. As the humans argued, wolf dogs ate scraps of discarded food. Smaller than wolves, they had been domesticated and were perfect for pulling heavy loads without overheating. But a few of the larger wolf dogs seemed able to pick up the scent of the large bears better than humans could. Some of the tribe wanted to breed and train these wolf dogs for hunting. Other hunters who were widely known for their olfactory skills might have been concerned that their specialty, their craft, was threatened by the more sensitive canine olfactory system.

This example is of course fanciful and contrived.<sup>1</sup> We don't know if labor debates took place under these circumstances, but humans have been transforming work and probably arguing about these transformations from our early days as hunters, gatherers, and traders.

---

<sup>1</sup>However, there is evidence that early domesticated dogs in Siberia may have been bred for pulling heavy weights possibly before they were bred for hunting. See Pitulko, V. V. and Kasparov, A. K. (2017). "Archaeological dogs from the Early Holocene Zhokhov site in the Eastern Siberian Arctic." *Journal of Archaeological Science: Reports*. 13: 491-515. doi: <https://doi.org/10.1016/j.jasrep.2017.04.003>.

In any case, within several generations, hunters in this region were likely acclaimed, not only for their courage in attacking large bears but also for the way they trained and communicated with hunting dogs. Status, ego, property rights—all the ingredients of drama and tragedy—were there from the beginning and intricately woven into the structure of work and tribal dynamics.

All animals work to survive. Humans, to date, are no exception. We work to produce food, shelter, and heat, we work to entertain each other, we work to teach others to produce and trade the things that we need and value, and we work to contribute to the well-being of our community. We also create machines and train animals in order to amplify our strength, endurance, dexterity, mobility, and (more recently) our communications and intelligence.

These machines and animals influence how we structure our culture. For example, clocks organize our day, impose structure in the workplace, and in the Seventeenth century provided a metaphor for how our brains worked.<sup>2,3</sup> More recently, the brain has been compared to switchboards (in the early days of telecommunications), to serial computers (with short-term and long-term storage, and data transfer), and to deep learning and self-organizing networks.

These defining technologies also provide a framework through which humans interact. But unlike previous technologies, the latest generation of machines (i.e., robots) are operating semi-autonomously. Within the narrow limits of a well-defined domain (such as games, exploration of the sea floor, driving a truck or car), they are beginning to make decisions based on immediate context and long-term goals.

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<sup>2</sup>Kilpatrick, J. (1985). Reflection and recursion. *Educational Studies in Mathematics*, 16(1), 1-26.

<sup>3</sup>Wiener, N. (1989). *The human use of human beings: Cybernetics and society* (No. 320). Free Association Press. Accessed through [https://monoskop.org/images/5/51/Wiener\\_Norbert\\_The\\_Human\\_Use\\_of\\_Human\\_Beings.pdf](https://monoskop.org/images/5/51/Wiener_Norbert_The_Human_Use_of_Human_Beings.pdf) [accessed on April 9, 2020].

This is not artificial general intelligence (AGI),<sup>4</sup> but it is at least the mimicry of human purpose and domain-specific intelligence. Just as computer architectures served as metaphors for how to think about ourselves and society, we need appropriate metaphors to help guide policy, technological research and invention, and application of robotics.

What is significant about this next phase of machine technology is that we are integrating intelligent, semi-autonomous robotics into the workplace, transforming cognitive tasks that were once considered “for humans only” such as social interactions, business process design, and strategic decision-making. AI, robotics, and automation represent the first large-scale substitute for human cognition.<sup>5</sup>

In this chapter we will explore how robotics might impact our household chores, jobs, and business, and military processes. We will examine the types of skills for which robots are well designed and the jobs or tasks that may or must have a human in the loop.

## Impact of Robotics on Work

There are many conflicting opinions about the impact of automation on the working population and on government and economic policies. In some scenarios, production no longer depends upon human labor; most production is accomplished through robots and automation, leaving most human workers unemployed. In such scenarios, the middle class may be eliminated, wealth disparity is increased, and wealth becomes increasingly dependent on inheritance and investment.

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<sup>4</sup>Artificial general intelligence, or “strong AI,” is a machine that can experience consciousness and autonomy and can perform any cognitive task that a human can.

<sup>5</sup>Rodney Wallace, personal communication based on a review of an early version of this chapter.

Even in less extreme scenarios, automation will be disruptive, and jobs will be replaced or transformed. Whether this will mean massive unemployment or post-scarcity affluence with guaranteed incomes and more satisfying creative work will depend on all of us. The world will be shaped by the policies and technologies that advanced economies adopt.

How will jobs and social structures be transformed? The early Industrial Age involved the large-scale transformation of steam into mechanical energy. The next major phase occurred when electricity was generated and transformed into mechanical energy or light. However, these technologies would not have transformed societies if not for social and business innovations that created large labor markets of skilled and unskilled workers, the factory organization, the corporation, insurance to mitigate investment risks, and so on. This in turn powered the modern consumer economy—the Information Age with its emphasis on novelty, efficiency, and mass consumption.

The recent history of technological adoption indicates that information technologies tend to devalue those jobs that are repetitive but cannot yet be automated. Skilled but nonexecutive jobs also tend to be transformed or replaced. Indeed, whole business processes are redesigned, eliminating tedious, unsanitary, or dangerous tasks and concentrating tactical everyday decisions into the jobs of fewer, but well-trained clerical and professional workers. Conversely, the same technological and economic pressures tend to value jobs that focus on networking, process design, and creativity.<sup>6</sup>

For example, long before mobile smartphones and networked computers were ubiquitous, ATMs and electronic banking led to the reduction of physical banks, the elimination of low-skilled bank

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<sup>6</sup>Castells, M. (1996). *The Rise of the Network Society. Volume I, The Information Age: Economy, Society and Culture*. Oxford, Blackwell.

employees, and the reduction of skilled data entry positions and bank clerks. The jobs of the remaining bank clerks were transformed; their focus shifted toward selling loans and other financial services.<sup>7</sup> Unlike previous mechanical technologies, information technologies replace not physical labor but predictable, repeatable cognitive labor. Technological and social innovations coevolve. New forms of organization enable adoption and adaptation of new technologies to further social, industrial, and individual goals.

We are now entering an era of intelligent robotics. To understand the potential impact on work, the next several subsections will review the impact of earlier industrial transformations on work and societal responses to automation. We will first consider reactions to the introduction of new technology in the textile industry, at the beginning of the Industrial Revolution.

## Resistance to the Industrial Age

The iconic Luddite rebellion against industrial technology was not a reaction to the transformation of unskilled labor, it was a response by highly paid, skilled craftsman to task simplification and rumors of automation.<sup>8</sup> General Ludd, the fictitious leader of the rebellion, was the creation of a secret society, *Luddites*, who through satire, and violence, protested the use of technology to drive down wages. The movement arose in March 1811, in the bleak economy of the Napoleonic Wars, in a market town about 130 miles north of London. Protesters smashed equipment such as shearing frames because owners were using them to replace highly

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<sup>7</sup>*Ibid*, p. 248.

<sup>8</sup>Conniff, R. (March 2011). What the Luddites Really Fought Against. *SMITHSONIAN MAGAZINE*. [www.smithsonianmag.com/history/what-the-luddites-really-fought-against-264412/](http://www.smithsonianmag.com/history/what-the-luddites-really-fought-against-264412/) [accessed on April 6, 2020].

paid croppers. Croppers were skilled textile workers who clipped the wool after it had been sheared.<sup>9</sup> The movement quickly spread, turned violent, and was subsequently suppressed by the British military.

What is notable about the actual Luddite rebellion (as opposed to the stuff of myth) is that the textile workers were not against technology or automation, per se. They wanted technology that would require skilled well-paid workers<sup>10,11</sup> and would produce high-quality goods. This concern, that technology should be crafted and evolved in sympathy with human values, is repeated throughout history, from Plato's description of the *Thamus'* critique of writing<sup>12</sup> to today's concerns about robotics.

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<sup>9</sup>"Luddites." International Encyclopedia of the Social Sciences. Encyclopedia.com: [www.encyclopedia.com/social-sciences/applied-and-social-sciences-magazines/luddites](http://www.encyclopedia.com/social-sciences/applied-and-social-sciences-magazines/luddites) [accessed on April 6, 2020].

<sup>10</sup>Jones, S. E. (2013). *Against technology: From the Luddites to neo-Luddism*. Routledge. However, in modern usage, the terms *Luddite* and *Neo-Luddite* tend to mean opposed to innovation and progress.

<sup>11</sup>The Luddite rebellion is often associated with *Jacquard looms*. However, these machines were not imported into England until the 1820s.

<sup>12</sup>Jowett, B. (2005). *Phaedrus by Plato*. In his dialogue with Phaedrus, Socrates summarizes a meeting between Theuth, who according to myth invented writing and many other inventions, and Thamus, who ruled all of Egypt. Theuth wanted to introduce his inventions to the Egyptians, for their benefit. Thamus was cautious and inquired about each invention and approved or disapproved of each, in turn. As for writing, Theuth claimed that it will improve wisdom and memory. Thamus replied that Theuth is biased toward his invention and that writing will increase forgetfulness because people will not use their memories. It will give people a false sense of truth, and "they will appear to be omniscient and will generally know nothing."

## The Information Age

In his brilliant three-volume 1996 study, *The Information Age: Economy, Society, and Culture*, Manuel Castells highlights the critical importance of human intelligence:

*The broader and deeper the diffusion of advanced information technology in factories and offices, the greater the need for an autonomous, educated worker able and willing to program and decide entire sequences of work.*<sup>13</sup>

The Information Age with its focus on the automation of work has unfolded along the lines predicted by the work of Castells and others.<sup>14</sup> Most notably, very low-skilled and very high-skilled jobs tend not to be replaced. It is a myth that automation targets only the lowest-paid workers. Rather, in the information economy, it is the highly repeatable information tasks that are replaced by automation (e.g., clerical jobs, sorting and routing of information, and filtering and archiving of significant documents and transaction records). As we shall see, AI and robotics are pushing the boundaries of what is meant by “repeatable information tasks.”

Understanding how jobs and tasks will be transformed requires an appreciation of how jobs and tasks are structured in information economies. Figure 1-1 is adapted from Castells 1996, *The Rise of the Network Society*. In his analysis of work transformation, he suggests a “new division of labor,” constructed around three dimensions. The first dimension is concerned with *value-making*, “the actual tasks performed in a given work process.” The second dimension, *relation-making*, refers to how work and organizations relate to one another. The third dimension,

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<sup>13</sup>Castells, M. (1996). *The Rise of the Network Society. Volume I, The Information Age: Economy. Society and Culture*. Oxford, Blackwell. p241.

<sup>14</sup>See, for example, Ford, M. (2015). *Rise of the Robots: Technology and the Threat of a Jobless Future*. Basic Books.