WORKING ALONGSIDE TECHNOLOGY: THE FUTURE OF THE WORKFORCE

A Research Paper submitted to the Department of Engineering and Society
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Engineering

By

Robyn Guarriello

March 27, 2020

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISOR
Catherine D. Baritaud, Department of Engineering and Society

Circuit design is a fundamental topic covered in courses taken by electrical and computer engineering students. At the University of Virginia in particular, students are required to take the Fundamentals of Electrical Engineering series, a three course sequence covering all aspects of circuitry. The first semester that a student begins these courses, it is mandatory for them to purchase a lab kit that contains circuit components. This kit includes, but is not limited to, operational amplifiers, capacitors, and, most notably, a large number of resistors. However, as labs become more difficult and take more time to complete, students often do not take the time to sort parts back into the appropriate bin. These misplaced components then lead to mistakes when constructing circuits in the future. Notably, if the wrong value of resistance is used, the circuit will not work as planned and, in some cases, will be unable to function at all. Though humans are prone to error that can lead to misplaced parts, a machine that sorts resistors semi-autonomously will not make the same error. Under the guidance of Electrical and Computer Engineering Professor Harry Powell and graduate electrical engineering student Riley Christopher, computer engineering students Robyn Guarriello, Joseph Laux, and Kiri Nicholson designed and built such a machine. With the system, users are able to scan a resistor using their smartphone, send the resistor value over a Bluetooth connection, and watch the system sort the resistor into the correct container.

However, automating low-skill tasks, such as sorting resistors, has become a polarizing topic in the world today. Automation creates the opportunity to progress society into a higher standard of living and productivity but presents the risk of displacing low skill workers from their jobs and source of income (Lordan and Neumark, 2018). Susan Lund, a labor economist with McKinsey says that "[automation] is how our children could end up with a better standard of living than we have. We want to be able to transition our workforce so that people displaced

can get new jobs and we can capture the benefits without the downside" (as cited in Paquette, 2017, para. 19). Tightly coupled with the technical topic, the Science, Technology, and Society (STS) research portion of the thesis identifies the gaps in the workforce that technology cannot fill in order to aid the smooth transition of the workforce, using Pinch and Bijker's (1984) Social Construction of Technology (SCOT) and W.B. Carlson's (2009) system in context SCOT framework to map the impact of automation in the workforce. Knowledge of where these gaps exist will help society understand what human capacities can be effectively capitalized on as the landscape of the workforce changes and diminish the fear surrounding automation. To achieve this, the history of automation and the controversy surrounding its growth will be analyzed, highlighting both the positive and negative impacts it has had on society, the current state of automation will be mapped using the system in context framework, and innate capabilities of humans will be compared with those of technology in order to illuminate the gaps in technology's abilities. Finally, the system in context framework will be revisited and revised to illustrate a solution where humans work effectively and productively alongside technology.

INCREASED AUTOMATION IN THE WORKPLACE

Technology has been developing for centuries, from the first wheel to the first quantum computer, allowing humans to save time and energy on tasks that a machine can do with great ease. Artificial intelligence (AI), machine learning (ML), and robotics have been increasingly adopted in the workplace, sustaining and increasing an overwhelming culture of fear surrounding the possibility of technology taking jobs from American workers. This increase of technology in the workplace can easily be seen throughout history. In the 1900s, Henry Ford adopted the assembly line to improve the system of building the Model T, and today nearly 30% of work hours are completed by AI and ML rather than humans, a number which is expected to grow to over 50% by 2025 (Gralla, 2019; Manyika et al., 2017).

However, the growth of automation has been greatly debated for as long as it has existed. In the 19th century, the Luddites became infamous for their fear of textile machines ruining their livelihood. They would destroy machines, set factories on fire, and attack employees in an attempt to stop the adoption of new technology (Andrews, 2019). More recently, Facebook announced in 2017 that they shut down an artificial intelligence project when the bots that were created developed a new language that was understandable only to the bots (Griffin, 2017). Though Facebook stated that the project was shut down only because the bots did not behave in the intended manner, the situation was portrayed by the media as a sign that technology has the ability to go rogue and harm humans (Griffin, 2017).

This dramatization by the media is one of the main factors that drives the fear of automation in society today. Sensationalist headlines in magazines, newspapers, and even scholarly articles such as “How Technology is Destroying Jobs” (Rotman, 2013), “Robots Could Take Over 38% of U.S. Jobs Within About 15 Years, Report Says” (Masunaga, 2017), and

"People Versus Machines: The Impact of Minimum Wages on Automatable Jobs" (Lordan, Neumark 2018) illustrate how society is framing the issue of automation in the workforce and the kind of media that is reaching consumers in their homes. As technology continues to grow and becomes an inevitable part of modern-day society, it is important to recognize from where the fear of technology stems and to question the biases of the mass media that all people are consuming today. Only by understanding the truth behind automation and the impact it has on the workforce will society be able to devise a solution that ensures all people benefit from the use of technology and society is able to progress into the future.

THE CHANGING LANDSCAPE OF THE WORKFORCE

There is no doubt that the adoption of technology in the workplace changes the landscape of the workforce as a whole. The emphasis placed on acquiring cheaper and more efficient labor will almost always lead towards implementing technology over hiring a human when it comes to repetitive and mundane tasks. This adoption of technology impacts low-skill and minimum wage workers more harshly than higher-skilled and salaried workers (Lordan & Neumark, 2018). This is illustrated by the change in hiring habits of companies around the country; employers are increasingly hiring those with advanced degrees over those with only a high school diploma or General Educational Diploma (GED) (Hufford, 2019).

In the same vein, jobs are being destroyed due to automation, and have been destroyed throughout history. Shortly after the personal computer was introduced, about 3,500 jobs in fields such as typewriter repair and bookkeeping became obsolete (Manyika et al., 2017). Today, the World Economic Forum, and international organization dedicated to improving the state of the world, states that 75 million jobs will be disrupted by the use of AI and robots in the workplace (as cited in Gralla, 2019; Our Mission, n.d.). As shown in Figure 1 on page 5, the

renowned global consulting firm McKinsey Global Institute found that over a quarter of jobs will automate over 70% of their tasks in the near future, putting nearly 33% of American workers at risk of being displaced from their current jobs (Manika et al., 2017). These statistics illustrate the potential negative impacts of automation and the feasibility that the entire landscape of the workforce will soon change, forcing nearly all occupations to alter the makeup of employees based on changes in technology, productivity, and employment costs.

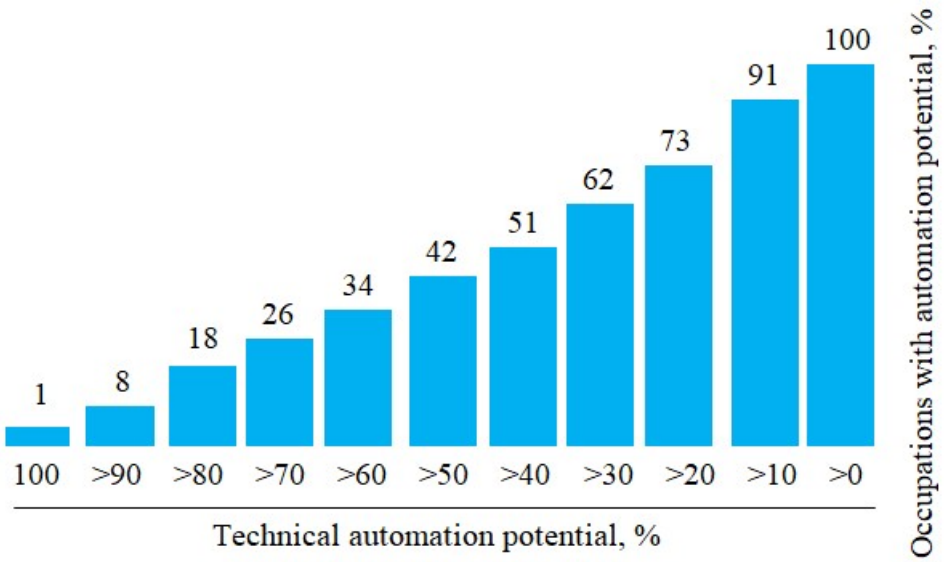

Figure 1: Potential of Automation: A bar chart showing the percent of occupations that have automatable tasks (adapted by Guarriello (2019) from Manyika et al., 2017 p. 27)

Nonetheless, there is great potential for automation to lead to the creation of new jobs which cannot be overlooked. While the personal computer led to 3,500 jobs becoming obsolete, it also led to nearly 20,000 jobs being created in new fields (Manyika et al., 2017). Likewise, the World Economic Forum states that 133 million jobs will be created due to the adoption of AI and robots in the workplace (as cited in Gralla, 2019). Thus the net change in the workforce due to automation has historically been, and is expected to continue to be, an increase in jobs. The personal computer led to a net gain of 16,500 jobs while experts believe that AI and robots will create a net gain of 58 million jobs (Gralla, 2019; Manyika et al., 2017). While it is easy to focus

on the potential for negative change in society, it is important to see the bigger picture and understand the progress that is within reach.

AUTOMATION IN CONTEXT TODAY

The current state of automation in the workforce is well modeled using W.B. Carlson's (2009) system in context framework, adapted from Pinch and Bijker's (1984) Social Construction of Technology theory. Figure 2 below shows SCOT framework centered on automation, which is the boundary object in the model. The social context surrounding the entire system is the fear of change.

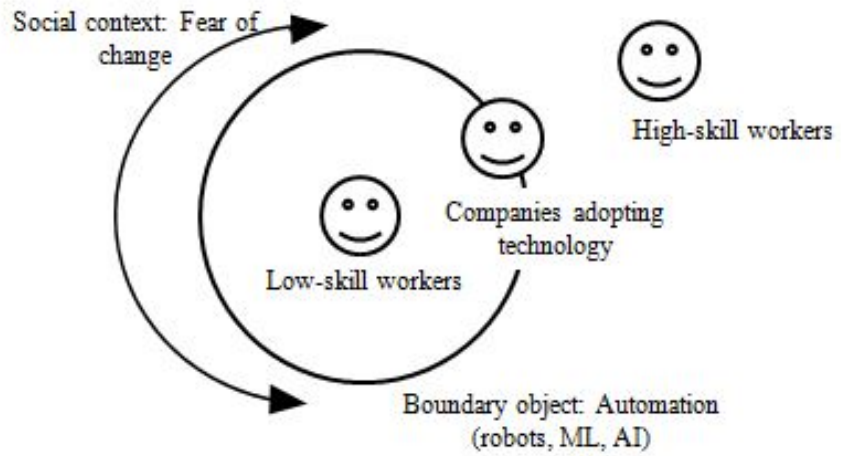

Figure 2: Current State of Automation Modeled with the System in Context Framework: The fear of change makes society as a whole wary of the changing landscape of the workforce due to automation, with each actor having a different amount of stake in the situation (adapted by Guarriello (2020) from W.B. Carlson, 2009).

The world has been changing for as long as it has been in existence, but change will always be uncomfortable. The unknowns that lie in change create the apprehension that keeps people from wholeheartedly moving forward with something new. Ultimately, companies are the ones that bring new technology into the workplace and the ones responsible for introducing the increase of automation. Thus they are the gatekeeper in the model. The most removed actors are high-skill workers because they are the least affected by the adoption of technology while the most affected actors are the low-skill workers, whose jobs rely on repetitive tasks that are susceptible to replacement by technology.

The current state of the model leaves low-skill workers subject to the decisions of companies that decide how much automation to incorporate in their workforce. Because these replaceable workers often do not have training or education for high-skill work, they are simply out of a job when the company opts to save money through the implementation of technology. This loss of control that low-skill workers face is the critical issue for which a solution must be found.

IDENTIFYING GAPS IN WORKFORCE AUTOMATION

Though many tasks in the workplace are able to be automated, not all tasks share the same fate. This inability of some tasks to be automated creates gaps in the workforce where technology cannot be adopted, and filling these gaps with human workers is the key to creating a prosperous workforce where humans work effectively alongside technology. To reap all of the rewards that the adoption of technology makes possible, the gaps in the workforce left open by technology must be identified and understood. Technology certainly has its limitations, and it is important for these limitations to be discussed in order for society to move forward, increase productivity, and diminish the fear surrounding automation.

Technology is undeniably good at completing tasks that follow patterns and rules. This means that simple tasks such as taking an order, or repetitive tasks such as screwing the same two pieces together over and over again are unequivocally better completed by technology, which can complete the same precise movements countless times, than humans, who are inherently prone to error and fatigue. This is why machines are widely used in manufacturing, why sewing machines are more efficient than hand sewing, and why a live fast food worker may get an order wrong, but a self-serve kiosk never will. Automation will continue to take over jobs in these fields simply because humans cannot keep up with their precision and accuracy.

While automation is putting human jobs in repetitive and low-skill fields at risk, it is also creating jobs in others. Melonee Wise, the CEO and founder of Fetch Robotics, says that "for every robot we put into the world, you have to have someone maintaining it or servicing it or taking care of it" (Pistrui, 2018, para. 6). Robots and technology cannot exist on their own, and human workers need the technical capacity to understand and maintain the technology. Programming robots, designing machines, training ML bots, and all other technical high-skill tasks are, for the most part, created and protected by the advancement of automation. For every piece of technology that is implemented, an expert must be employed to ensure it continues to work as needed and to make updates as necessary. For every task that employers want to automate, a team of researchers must work countless hours to produce the best product. For every outdated piece of technology, an inventor must create an improved replacement. These technical high-skill jobs are those that are created by automation and are just one of the benefits society can reap from automation.

However, one area of the workforce that automation does not have the ability to penetrate as harshly is the creative fields. Technology lacks ability in environments that require emotion and creative thought. Lars Geer Hammershøj (2019), an associate professor at Aarhus University, the largest research university in Denmark, and a researcher known for his work regarding creativity and educational systems , states that humans have a unique capacity to think creatively and draw connections between seemingly unconnected ideas ("Lars Geer Hammershøj, Associate Professor," n.d.). While computers work inside fixed matrices for which rules can be defined, creativity inherently lies between matrices. That is, creativity is the ability to operate outside the rules of a matrix and instead draw connections between different matrices or change the existing rules. John Smith, the manager of multimedia and vision at IBM research,

agrees, saying “it’s easy for AI to come up with something novel just randomly. But it’s very hard to come up with something that is novel and unexpected and useful” (The Quest for AI Creativity, n.d., para. 7). Humans have the unique capability to be truly creative, to understand when old rules no longer apply, and thus to create change themselves. This is the area that is virtually untouchable by automation compared to the rest of the workforce. Creativity is inherently human, and is where the future of the workforce lies.

CAPITALIZING ON CREATIVITY

As illustrated, the two main areas where humans are needed in the wake of automation are technical work and creative work. Technical skills, sometimes referred to as hard skills, are often the focus of education (Hammershøj, 2019). Schools teach mathematics, computer programming, and other hard subjects; however, there is not as much focus on soft skills, creativity, and empathy. Examples of activities that fall into this category of creativity are management, communication, and making emotional connections (Manyika et al., 2017). These skills must be nurtured and grown so that humans can capitalize on the unique capabilities that technology is not able to truly mimic.

To combat the loss of jobs that is inevitable due to the rise of automation, society must focus on providing re-education for those that are put out of a job to either gain technical skills or to think creatively. Additionally, implementing lessons in the educational system that teach empathy, communication, and innovative thinking will prepare the future generations for the workforce that they will grow into, and prepare the future of society to prosper. Applying these changes, the system in context framework outlined in Figure 2 on page 6 can be modified to show the potential for humans to work alongside technology rather than simply fear technology. On page 10, Figure 3 shows these modifications with three main changes presented. First, the

social context surrounding the system has been changed from “fear of change” to “fostering creativity and innovative thought”. In order for society to move forward, it must not be fearful of change. Change leads to progress, and the only way for society to move forward, by definition, is through progress. Therefore, it is essential that society diminishes the fear surrounding automation as much as possible to aid in movement towards the future. Secondly, the most removed actor, high skilled workers, has been broken up into two separate actors. Because the two main areas of work that have been distinguished as being the most resistant to automation are technical work and creative work, the removed actor is better defined by a separation into technical workers and creative workers, both of which will thrive in the changing landscape of the workforce. Finally, new arrows point from low-skill workers to both technical workers and creative workers. These arrows represent the ability of low-skill workers to transition into either technical or creative roles. If creative and innovative thought is prioritized alongside technical knowledge in schools and educational systems, then low-skill workers will be able to transition out of their jobs into occupations that are less susceptible to automation.

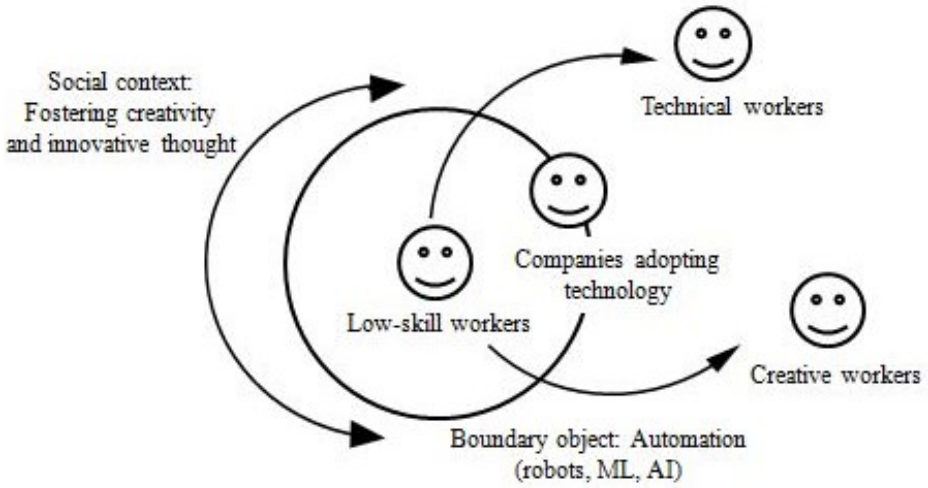

Figure 3: Future of Automation Modeled with the System in Context Framework: If society focuses on fostering creativity and innovative thought, low-skill workers will be able to transition into fields that are less susceptible to automation. This allows companies to prosper from the higher productivity allowed by automation and workers to prosper doing work of which only humans are capable (adapted by Guarriello (2019) from Carlson, 2009)

Humans are responsible for reaping all of the benefits possible from technology while diminishing the negative impacts. One of the main factors that is hindering progress is the fear surrounding the increased adoption of technology in the workforce. Fear that robots will become fully autonomous, that all jobs will be done by automation, or that artificial intelligence will become too smart for humans to contain is unfounded and detrimental to the future of society. In the words of Hammershøj (2019), "computers and robotics appear to have made rapid change possible, but cannot solve the task of change themselves" (p.2). This inability of technology to enact change leaves humans responsible for creating change themselves. This means that humans will always be in the driver's seat when it comes to the future of automation. The educational system must prepare students to work in the new landscape of the workforce by fostering innovative thought and emotional connections. The advancement of technology has not always led to ideal outcomes, but if society invests in the future, there is no telling just how prosperous society can become.

WORKS CITED

Andrews, E. (n.d.). *Who were the Luddites?* Retrieved from https://www.history.com/

Baritaud, C. (2009, August 26). *Conceptual frameworks*. Retrieved from https://collab.its.virginia.edu/access/content/group/c43094d1-1346-4b3c-b722-65cf08e85e28/Conceptual%20Frameworkds/Conceptual%20Frameworks.pdf

Bijker, W., & Pinch, T. (1984). The social construction of facts and artifacts: Or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science, 14(3)*, 399-441. Retrieved from www.jstor.org/stable/285355

Gralla, P. (2019, August 20). AI by the numbers. *Hewlett Packard Enterprise.* Retrieved from http://hpe.com/

Griffin, A. (2017, July 31). *Facebook's artificial intelligence robots shut down after they start talking to each other in their own language.* Retrieved from https://www.independent.co.uk/

Guarriello, R. (2019). *Potential of automation.* [Figure 4]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Guarriello, R. (2020). *Current state of automation modeled with the system in context framework.* [Figure 1]. *STS Research Paper: The Changing Landscape of the Workforce Due to Automation* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Guarriello, R. (2020). *Future of automation modeled with the system in context framework.* [Figure 2]. *STS Research Paper: The Changing Landscape of the Workforce Due to Automation* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Hammershøj, L.G. (2019). The new division of labor between human and machine and its educational implications, *Technology in Society, 59,* 1-6. doi:10.1016/j.techsoc.2019.05.006

Hufford, A. (2019, December 10). American factories demand white-collar education for blue-collar work. *The Wall Street Journal*. Retrieved from https://www.wsj.com/

Lars Geer Hammershøj, Associate Professor. (n.d.). *British Educational Research Association.* Retrieved from https://www.bera.ac.uk/

Lordan, G., & Neumark, D. (2018). People versus machines: The impact of minimum wages on automatable jobs. *Labour Economics*, *52*, 40–53. https://doi.org/10.1016/j.labeco.2018.03.006

Manyika, J., Lund, S., Chui, M., Bughin, J., Woetzel, J., Batra, P., … Sanghvi, S. (2017). *Jobs lost, jobs gained: Workforce transitions in a time of automation*. Retrieved from https://www.mckinsey.com/

Masunaga, S. (2017, March 24). Robots could take over 38% of U.S. jobs within about 15 years, report says. *Los Angeles Times.* Retrieved from https://www.latimes.com/

Our mission. (n.d.) *World Economic Forum*. Retrieved from http://www.weforum.org/

Paquette, D. (2017, November 30). Robots could replace nearly a third of the U.S. workforce by 2030. *Washington Post.* Retrieved from https://www.washingtonpost.com/

Pistrui, J. (2018, January 18). The future of human work is imagination, creativity, and strategy. *Harvard Business Review.* Retrieved from http://hbr.org/

The quest for AI creativity. (n.d.). *IBM*. Retrieved from http://www.ibm.com/

Rotman, D. (2013, June 12). *How technology is destroying jobs.* Retrieved from https://www.technologyreview.com/

BIBLIOGRAPHY

Andrews, E. (n.d.). *Who were the Luddites?* Retrieved from https://www.history.com/

Baritaud, C. (2009, August 26). *Conceptual frameworks*. Retrieved from https://collab.its.virginia.edu/access/content/group/c43094d1-1346-4b3c-b722-65cf08e85e28/Conceptual%20Frameworkds/Conceptual%20Frameworks.pdf

Bijker, W., & Pinch, T. (1984). The social construction of facts and artifacts: Or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science, 14(3)*, 399-441. Retrieved from www.jstor.org/stable/285355

Blom, J. (n.d.). *Bluetooth basics*. Retrieved from https://learn.sparkfun.com/

Chonowski, K. (2017, April 29). *How to read resistor color codes*. Retrieved from https://www.arrow.com/

Griffin, A. (2017, July 31). *Facebook's artificial intelligence robots shut down after they start talking to each other in their own language.* Retrieved from https://www.independent.co.uk/

Gross, B., Lambert, N., & Parkhurst, A. (2016). *Automated resistor sorter with GUI.* Retrieved from http://people.ece.cornell.edu/

Guarriello, R. (2019). *Automation modeled with the technology and social relationships framework.* [Figure 6]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Guarriello, R. (2019). *Gantt chart for projected project timeline.* [Figure 1]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Guarriello, R. (2019). *Potential of automation.* [Figure 4]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Guarriello, R. (2020). *Current state of automation modeled with the system in context framework.* [Figure 1]. *STS Research Paper: The Changing Landscape of the Workforce Due to Automation* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Guarriello, R. (2020). *Future of automation modeled with the system in context framework.* [Figure 2]. *STS Research Paper: The Changing Landscape of the Workforce Due to Automation* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Hammershøj, L.G. (2019). The new division of labor between human and machine and its educational implications, *Technology in Society, 59,* 1-6. doi:10.1016/j.techsoc.2019.05.006

Hufford, A. (2019, December 10). American factories demand white-collar education for blue-collar work. *The Wall Street Journal*. Retrieved from https://www.wsj.com/

Lars Geer Hammershøj, Associate Professor. (n.d.). *British Educational Research Association.* Retrieved from https://www.bera.ac.uk/

Lordan, G., & Neumark, D. (2018). People versus machines: The impact of minimum wages on automatable jobs. *Labour Economics*, *52*, 40–53. https://doi.org/10.1016/j.labeco.2018.03.006

Manyika, J., Lund, S., Chui, M., Bughin, J., Woetzel, J., Batra, P., … Sanghvi, S. (2017). *Jobs lost, jobs gained: Workforce transitions in a time of automation*. Retrieved from https://www.mckinsey.com/

Masunaga, S. (2017, March 24). Robots could take over 38% of U.S. jobs within about 15 years, report says. *Los Angeles Times.* Retrieved from https://www.latimes.com/

Nicholson, K. (2019). *Block diagram*. [Figure 1]. *Band Pass Filters Resistor Sorter* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

OpenCV. (n.d.). *About.* Retrieved November 15, 2019, from https://opencv.org/

Our mission. (n.d.) *World Economic Forum*. Retrieved from http://www.weforum.org/

Paquette, D. (2017, November 30). Robots could replace nearly a third of the U.S. workforce by 2030. *Washington Post.* Retrieved from https://www.washingtonpost.com/

Pistrui, J. (2018, January 18). The future of human work is imagination, creativity, and strategy. *Harvard Business Review.* Retrieved from http://hbr.org/

The quest for AI creativity. (n.d.). *IBM*. Retrieved from http://www.ibm.com/

Rotman, D. (2013, June 12). *How technology is destroying jobs.* Retrieved from https://www.technologyreview.com/