ROBOTS AT WORK: HOW WILL ARTIFICIAL INTELLIGENCE IN THE WORKPLACE AFFECT HIGHER EDUCATION?

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March 31, 2018

Abstract

We examine the impact of automation technology on the labor market and assess how this affects higher education. To do so, we begin by analyzing automation in the past and how it affected the labor market. In the second section, we analyze the state of the upcoming automation technology and the "human skills" it has acquired. We then analyze the education and skills relating to various occupations and link it to the data on occupational probabilities of automation. To gauge the automation probability of these skills, we assess their category based on 18 key human competencies which have been studied and have associated rates of automation potentials from a study by McKinsey Global Institute, 2017. Findings show that nearly 42% of Canadian labor is at high risk of being affected by automation and about 18% of the labor has at least 70% of their work activities that can be automated.

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1. INTRODUCTION

The development of Robots that will be capable of self-governed movement, cognitive decision making and performing a wide range of activities has inspired much interest and research in the 21st century. [1] Robots are no longer a topic of science fiction but have become a feasible reality, hence, the discussions about their impact on the economy have gained much popularity in the media. Artificial Intelligence has become a major research topic in essentially every educational field including Science, Engineering, Medicine, Law, Business, Economics, Finance and many more, due to the possibility of its application in a wide variety of fields. [2] Many prominent leaders, researchers, academics and technologists are a part of popular social debates, on the potential impacts of this technology on our daily lives, which have yielded several competing points of view.

It is notable that it is not the first time that technology with broad industrial applications, and potential to affect a huge number of employees, is being introduced into the market. [3] Artificial intelligence technology is deemed to be the fourth industrial revolution which is set to happen in the near future. [3] As has been the trend in public belief, people fear that upcoming technologies will take over all the jobs. A research paper by Michael Jensen, the president of American Finance Association 1993, reveals some public interviews on the people's opinion on the topic. He finds people believe that, "The fruits of the toil of millions are boldly stolen to build up colossal fortunes for the few…" [4] The "Luddite" protests in Britain were a major effect resulting from the fear that laborers had of losing jobs to machines. [5] Scholars Erik Brynjolfsson and Andrew McAfee (2014) reveal in their recent study, "The Second Machine Age", that, "…there has never been a worse time to be a worker with 'ordinary' skills and abilities to offer, because computers, robots, and other digital technologies are acquiring these skills and abilities at an extraordinary rate."[6] It is natural for people to think that if machines are being developed to do their work, then what will they do?

In his study, "Why are there still so many jobs?" economist David Autor tries to this question and explain the impact that automation technology has on the labor market. He stands by Bowen (1966), who proposes that, "What worries many job experts more is that automation may prevent the economy from creating enough new jobs…" [7] Autor explains from his findings that, "…technological change (along with other forms of economic change) is an important determinant of the precise places, industries, and people affected by unemployment. But the general level of demand for goods and services is by far the most important factor determining how many are affected, how long they stay unemployed, and how hard it is for new entrants to the labor market to find jobs. *The basic fact is that technology eliminates jobs, not work.*" [7] He proposes that, "…the past two centuries of automation and technological progress have not made human labor obsolete: the employment-to-population ratio rose during the 20^{th} century even as women moved from home to market; and although the unemployment rate fluctuates cyclically, there is no ultimate long-term increase." His outlook on the topic is seconded by the findings of McKinsey Global Institute (2017) who report in their study, "A Future That Works", that based on their scenario model, they estimate an annual, global productivity growth of 0.8 to 1.4 percent due to automation in industry. [8]

Consequently, in favor of technological progress, Autor suggests that, "Automation does indeed substitute for labor-as it is typically intended to. However, automation also complements labor, raises output in ways that lead to higher demand for labor, and interacts with adjustments in labor supply…I argue that the interplay between machine and human comparative advantage allows computers to substitute workers in performing routine, codifiable tasks while amplifying the comparative advantage of workers in supplying problem-solving skills, adaptability, and creativity." [7] Frey and Osborne (2017) similarly report that, "…with falling prices of computing, problem-solving skills are becoming relatively productive, explaining the substantial employment growth in occupations involving cognitive tasks where skilled labor has a comparative advantage, as well as the persistent increase in returns to education…" [5]

As such, although there are numerous conflicting viewpoints, the common ground is that it is certain that the upcoming automation technology will indeed affect our lives in ways more than one. In fact, some scientists like Ray Kurzweil propose that these technological advances are proceeding at rapid exponential rates and hint to the arrival of "Technological Singularity" in the near future." [9] Brynjolfsson and McAfee (2011) describe that computerization is no longer confined to just routine manufacturing jobs. [19] Lamb (2017) reports that among the top five jobs that are at high risk of automation in Canada are: Retail Salesperson, Administrative Assistants and Food Counter Attendants which are jobs that are not simply routine and repetitive. [10] Another major instance is the progress companies like Google have made in developing autonomous driverless cars hence showing how manual activities in transport and logistics could be soon automated. [8] In 2017, the International Federation of Robotics (IFR) reported that robots are in great industrial demand and already rapidly being employed in major industries like the automotive and electrical/electronic industries all over the world. A press release by IFR showed that automation of production has rapidly increased from a global robot density of 66 robot units per 1,000 employees in 2015 to 74 units per 1,000 employees in 2017. [11]

In this study, we analyze the susceptibility of higher educational skills to being automated in the next 10 – 20 years by the introduction of automation technology in the workplace. We assess the impact automation technology is deemed to have on the labor market and identify the learnt skills that are highly resilient to being automated.

For this, we approach the topic from a skill-based point of view. We analyze how the labor market was previously affected by automation in the second section of this report. In section 3, we look at an overview of the state of the AI technology and the "skills" that it is being developed to perform. We then assess data from previous studies on the impacts of automation on the various occupations in Canada [10], computerization of occupations [5] and automation analysis 18 key human competencies. [8] For this, we relied on methodologies and findings from Oxford professors Carl Benedikt Frey and Michael Osborne from their article entitled "The future of employment", findings from McKinsey and Company (MGI) from their project entitled "A Future That Works" and a study by Brookfield Institute for Innovation + Entrepreneurship entitled "Talented Mr. Robot".

These sources provide the methodologies and algorithms developed by experts to analyze automation probabilities and obtained occupation-specific statistics. Using data from the Government of Canada [12] on careers by essential skills, we assess the higher educational skills applied in the various occupations. We then analyze these skills in relation to the data regarding the 18 key human competencies to obtain an estimate of the automation potentials of the different skills.

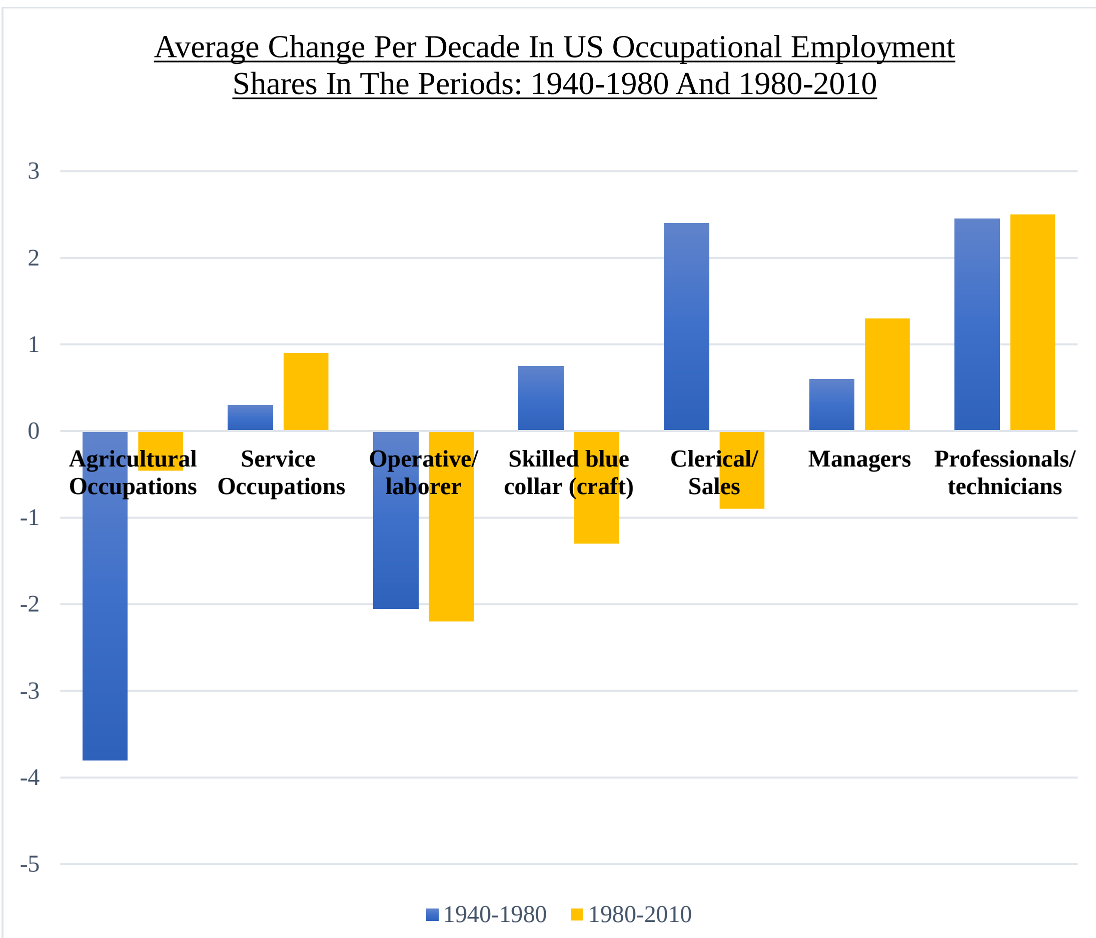
This provides an overview of the automatable and the necessary aspects of different occupations. In section 6, we create an appendix to present the data on the occupations, automation potentials of the skills they involve, educational requirements, and the probability of automation of the jobs.

In conclusion, striking facts from findings by the Brookfield Institute in their project, “The Talented Mr. Robot”, report that approximately 42% of the Canadian Labor force is susceptible to being affected by automation in the next 10 – 20 years. Moreover, about 18% of the Canadian labor force have at least 70% of their work activities that could be automated. Using the Canadian Occupation Projection System (COPS), they found that occupations with the highest resilience to automation are projected to produce nearly 712,000 net new jobs from 2014 – 2024, which emphasizes the need focus on these automation-resilient skills when training students in higher educational institutions, so that they can be successful in securing a spot in the industry. [10]

2. AUTOMATION AND EMPLOYMENT

There have been recurrent worries that automation and new technologies are bound to wipe out many middle-class jobs. [4] In fact, the introduction of advanced robotics and artificial intelligence technology in the workplace is deemed to be the fourth industrial revolution and is set to happen in the near future. [3] Industrial revolutions have thus occurred thrice in the past.[3] Data from the impacts of industrial revolution can provide information on how labor markets were previously affected, how occupations adapted in the past, skills that became obsolete and skills that became even more necessary. [7]

Below is a graph developed by Autor (2015) showing the impact on the job market in various industries during the times of major industrial revolution.

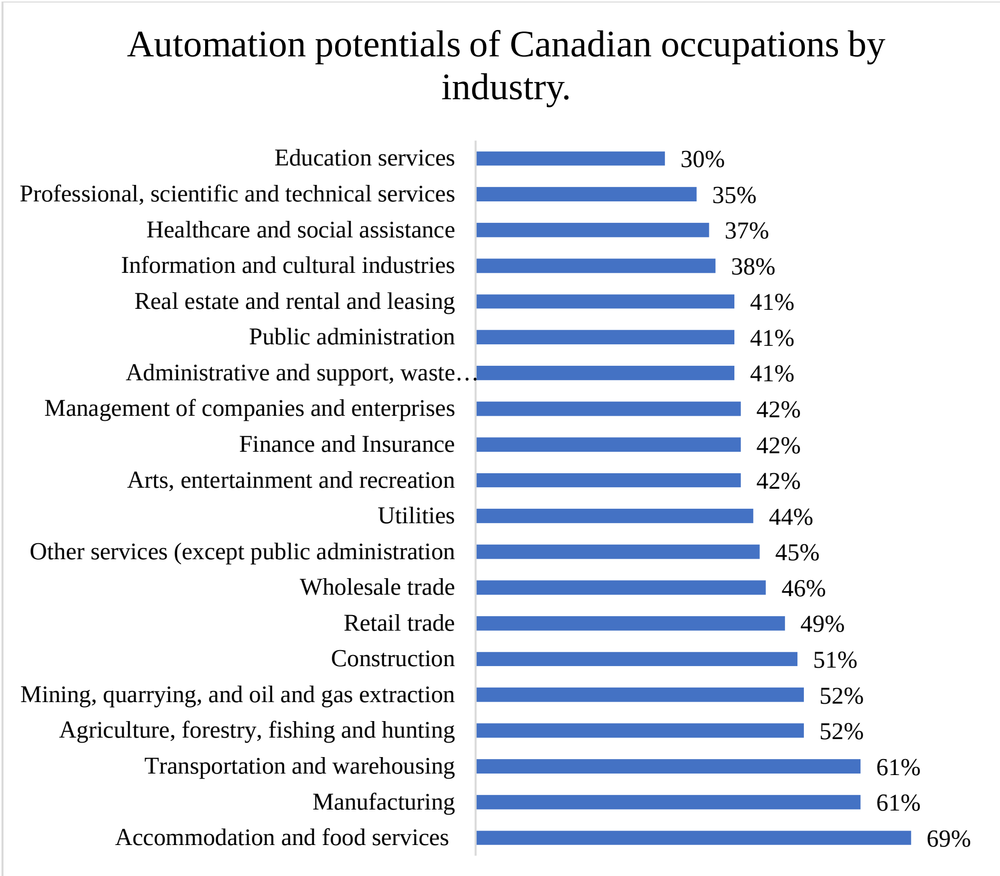


From this graph, it can be inferred that majority of the middle-class jobs saw a net reduction in the number of jobs available during the periods of major industrial automation. Net growth occurred in the number of jobs in the high-level management industries and low-level service industries. Autor explains this trend as an effect of the adoption of industrial automation technology that led to labor market polarization. [7]

He explains that laborers performing routine tasks were displaced by machines and thus sought employment in the upper-class management and lower-class service industries hence the rise in their share of the labor market over the years. This is, arguably, because these jobs involve large amounts of *physical adaptability* and *flexibility* which makes them hard to be computerized. [14] Goos and Manning (2007) report a similar observation of the market trend in their study "Lousy and Lovely Jobs." [14] During this time of market restructuring, it became necessary to gain more education and understanding about the digital technology, thus, making education a key component of job security. [14] A more modern example is the extensive use of computers. Job displacement has occurred due to extensive industrial use of computers which are being used to collect, manage and present data, organize forms, schedule activities and manage payrolls among other activities, which in the past were tasks meant for humans to perform. [15] However, their widespread application eventually created a tremendous amount of jobs which require high levels of education to secure.

In Canada, the proportion of the workforce with university education that is at high risk of automation is about 12.7% while those at low risk of automation are at 45.6%. [10] It can thus be inferred that some educational programs need to adapt to develop professionals that can fit in to the market. Nonetheless, it also becomes clear that occupations requiring high levels of education are at less risk of automation. In their study, MGI suggest that, over the years, researchers have recommended increased emphasis on the STEM (science, technology, engineering and mathematics) fields to secure jobs in the industry as it continuously adopts automation procedures, however, they now recommend further improvement of basic skills in the STEM fields and increased emphasis on *creativity* and *critical and systems thinking.* [8]

The graph below represents the automation potentials of Canadian occupations in the different industries as determined by Brookfield Institute. [10]



Statistics from the Brookfield Institute and MGI on automation by industrial sector can be viewed through interactive tables which provide a much-detailed overview of the information. [16], [17]

As such, it is found that among the Canadian occupations, the following jobs are listed as the top 5 low risk occupations: [10]

1. Retail and wholesale trade managers - 20.5%
2. Registered nurses (psychiatric included) - 0.9%
3. Secondary school teachers - 0.8%
4. Early childhood educators and assistants - 0.7%
5. Elementary and kindergarten teachers - 0.4%

It is observable that these jobs are either white-collar jobs or low-level service jobs which consistent with the findings over the years that these two labor group quartiles are least affected by automation.

Information on other occupations that are estimated to be at low risk of automation, their skills and the extent to which these occupations will be affected can be found in the appendix in Section 6 of the report.

However, it is notable that despite the declining need for labor in some fields, research shows that as a long-term effect, economies flourished due to increased productivity. Greatly increased productivity has been the major driving factor behind the interest and motivation to constantly innovate and develop new forms of industrial technology. MGI predict that based on their scenario model, they estimate an annual, global productivity growth of 0.8 to 1.4 percent due to automation. [8] Therefore, although these technologies can displace existing jobs, it is acknowledgeable to realize they could also be significant job creators and can boost productivity and living standards. [10] In recent years, a study by Deloitte UK using the criteria set by Frey and Osborne in their study, “From brawn to brains” finds that the occupations with low risk of automation had a job growth of 3.5 million jobs in the UK, as opposed to the estimated 800,000 jobs that were lost from the jobs with high risks of automation. [18]

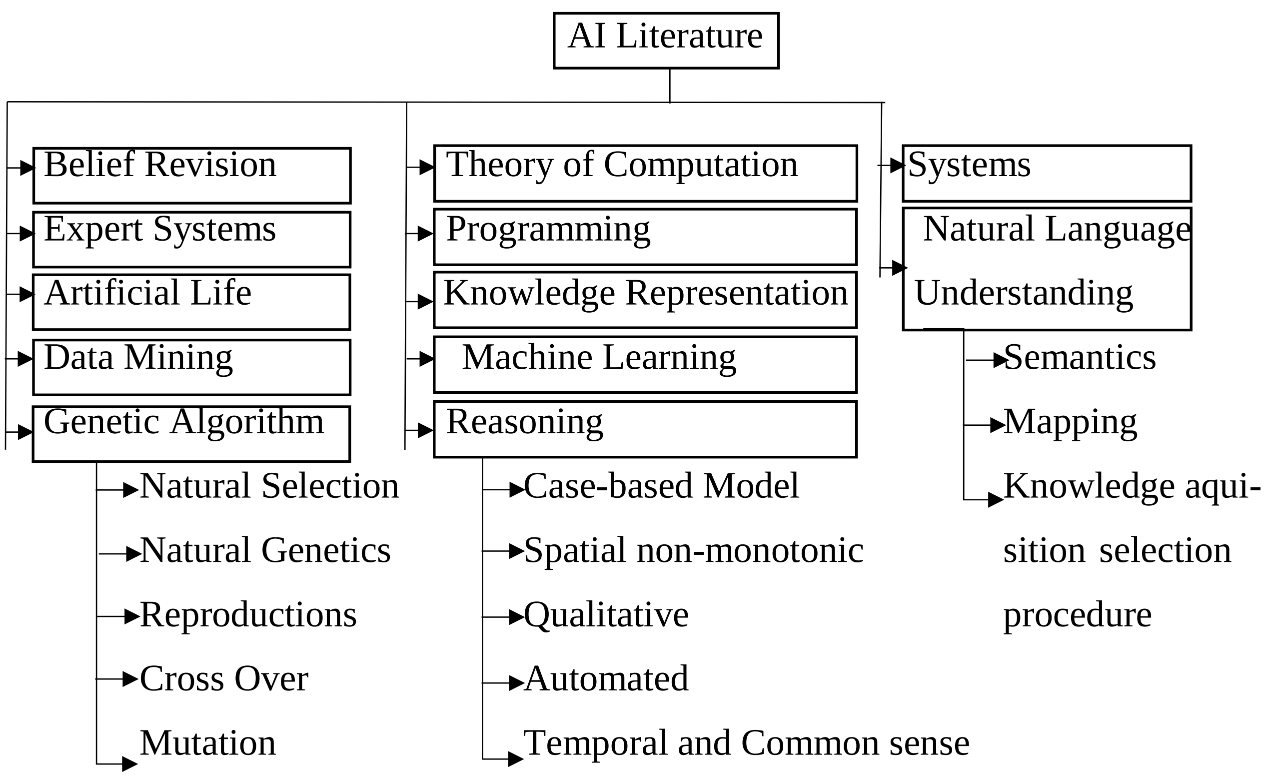
This shows how the productivity greatly increased after adopting mechanization. Economist Autor suggest this is because although automation displaces labor, it contributes to increased demand for *skilled* labor due to largely increased productivity. [7] Lamb remarks in his study that, “This implies that the benefits of this technology will be able to offset its shortcomings.” [10] Also, according to Oxford researchers Frey and Osborne, “Despite the shortcomings, automation has furthered economies by increasing productivity and creating higher-level jobs. It is also notable that despite the impacts on the labor market, researchers found that employment was still on the rise.” [5]

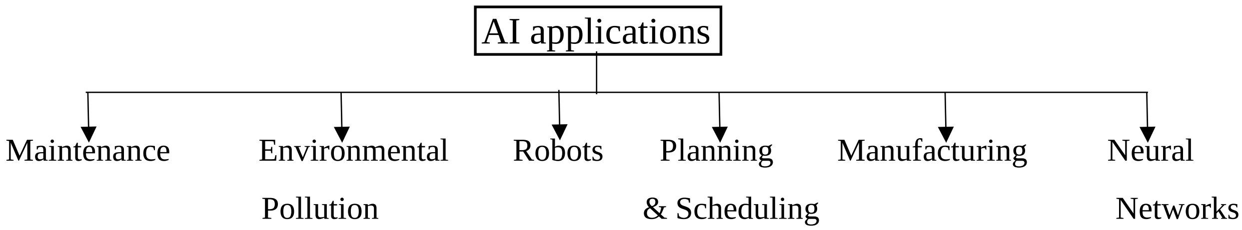
As such, automation of tasks leads to displacement of labor involving skills that are mechanizable through available sets of data and thus emphasizes the need for further education and skills to be a part of the labor force effectively.

3. CURRENT STATE OF AUTOMATION TECHNOLOGY.

We investigate the advancements that have been made in the artificial intelligence field to get an overview of the human skills that machines are being designed to perform and the industries that they apply to. This will make it possible to deduce various skills that are prone to being automated and those that will become even more necessary because they cannot be easily automated, or they complement the new technology.

On a broad-scale, the major sectors of development and application of artificial intelligence are classified into sixteen major sections. These being: reasoning, programming, artificial life, belief revision, data mining, distributed AI, expert systems, genetic algorithms, systems, knowledge representation, machine learning, natural language processing, neural networks, theorem proving, constraint satisfaction, and theory of computation. [2] Each of these fields uniquely applies artificial intelligence to perform human tasks. The flowchart below by Dr. Oke, shows the relationships between the various fields of artificial intelligence and the major areas of its application. [2]





MGI provide an overview of the major techniques and technologies used for automation today. The table below summarizes these techniques and describes the major processes they involve.[8]

Technologies &Techniques	**Descriptions/Examples**	
Artificial Intelligence (AI) / Cognitive Computing	Field of computer science specializing in developing systems that exhibit "intelligence".	
	Machine Learning	Subfield of AI developing systems that "learn" i.e. practitioners "train" these systems rather than "programming" them.
	Supervised Learning	Machine learning techniques that train a system to respond appropriately to stimuli by providing a trained set of sample input and desired output pairs. It has been used for email spam detection by training systems on a large number of emails, each of which was manually labelled as spam or not.
	Transfer Learning	Subfield of machine learning used in developing systems that store knowledge gained while solving one problem and applying it to a different but related problem. Used when the training set for one problem is small, but the training data for a related problem is plentiful e.g. repurposing a deep learning system trained on a large non-medical image data set to recognize tumors in radiology scans
	Reinforce-ment Learning	Subfield of machine learning developing systems that are trained by receiving virtual "rewards: or :punishment" for behaviors rather than the supervised learning on correct input-output pairs. In February 2015, DeepMind described such a system that learned to play a variety of Atari computer games, while in March 2016, its AlphaGo system defeated the world champion of Go.
Neural Networks	Artificial Neural Network	AI systems based on stimulating connected "neural units", loosely modelling the way that neurons interact in the brain. Computational models have been studied since 1940.
	Deep Learning	Use of neural networks that have "deep/many layers of a large number of artificial neurons. Prior to deep learning, artificial neural networks often had three layers and dozens of neurons: now these networks have 7-10 or more layers.
	Convolutional neural network	Artificial neural networks in which the connections between neural layers are inspired by the organization of the animal visual cortex, the portion of the brain that processes images,

		well suited for perceptual tasks. In 2012, the only entry using a convolutional neural network achieved an 84% correct score in the ImageNet visual recognition contest, vs. a winning score of 75% the year prior. Since then, convolutional neural networks have won all subsequent ImageNet contests, exceeding human performance in 2015, above 90%
	Recurrent neural network	Artificial neural networks whose connections between neurons include loops, well-suited for processing sequences of inputs. In November 2016, Oxford University researchers reported that a system based on recurrent neural networks (and convolutional neural networks) had achieved 95% accuracy in reading lips, outperforming experienced human lip readers, who tested at 52% accuracy.
Robotics	Soft robotics	Non-rigid robots constructed with soft and deformable materials that can manipulate items of varying size, shape and weight with a single device. Soft Robotics Inc. grippers can adaptively pick up soft foods (e.g., baked goods, tomatoes) without damaging them.
	Swarm robotics	Coordinated multi-robot systems, often involving large numbers of mostly physical robots
	Tactile/touch robotics	Robotic body parts (often biologically inspired hands) with capability to sense, touch, exhibit dexterity, and perform variety of tasks
	Serpentine robots	Serpentine looking robots with many internal degrees of freedom to thread through tightly packed spaces
	Humanoid robots	Robots physical similar to human beings (often bi-pedal) that integrate variety of AI and robotics technologies and are capable of performing variety of human tasks (including movement across terrains, object recognition, speech, emotion sensing, etc.). Aldebaran Robotics and Softbank's humanoid Pepper robot is being used to provide customer service in more than 140 Softbank Mobile stores in Japan
Automation product categories	Autonomous cars and trucks	Wheeled vehicles capable of operating without a human driver. In July 2016, Tesla reported that its cars had driven over 130 million miles while on "Autopilot." In December 2016, Rio Tinto had a fleet of 73 driverless trucks hauling iron ore 24 hours/day in mines in Western Australia
	Unmanned aerial vehicles	Flying vehicles capable of operating without a human pilot. The unarmed General Atomics Predator XP UAV, with roughly half the wingspan of a Boeing 737, can fly autonomously for up to 35 hours from take-off to landing
	Chatbots	AI systems designed to simulate conversation with human users, particularly those integrated into messaging apps. In December 2015, the General Services Administration of the US Government described how it uses a chatbot named Mrs.

		Landingham (a character from the television show The West Wing) to help onboard new employees
	Robotic process automation	Class of software “robots” that replicates the actions of a human being interacting with the user interfaces of other software systems. Enables the automation of many “back office” (e.g., finance, human resources) workflows without requiring expensive IT integration. For example, many workflows simply require data to be transferred from one system to another

The above techniques show the manner in which automation technology is being applied to perform tasks in 5 major areas of human performance: Sensory perception, Cognitive capabilities, Natural language processing, Social and emotional capabilities and Physical capabilities. [8] The activities people perform in the workplace are directly or indirectly a part of these major areas of performance. Consequently, the advancements in different areas of human performance depict the extent to which certain tasks in a job will be automated. In the next section, we shall look at statistics of a research carried out by MGI which shows the extent to which 18 different human capabilities are prone to automation because of the current automation technology. The above diversity in automation techniques largely increases the possibility of applying automation to almost every field.

Studies and experiments carried out to test the competencies of automation technologies versus human performance have shown the rapid learning mechanism of machines and how they have outperformed humans in several tasks. The IBM supercomputer Deep Blue defeated the world chess champion, Garry Kasparov, in 1997 and after fourteen years, another artificial intelligence system, IBM’s Watson defeated two champions in Jeopardy to win $1 million. [9] Google’s DeepMind and the University of Oxford also carried out a study where they used deep learning to study a big data set of BBC programs to create a lip-reading system. This program was then trained using more than 5000 hours of BBC TV programs involving over 100,000 sentences, which easily bested a professional lip-reader. This entailed a test of over 200 random clips in which the computer registered 46.8% error-free words while the human professional registered 12.4% error-free words. In this analysis entitled “Intelligent Machines vs. Human Intelligence”, Tsin Yen Koh provides further instances of when machine outperformed man. [9]

4. METHODOLOGY.

To develop an understanding of the skills most vulnerable and most resilient to automation, we used data and findings of McKinsey & Company, Frey and Osborne and Brookfield Institute for Innovation + Entrepreneurship. Oxford professors Frey and Osborne developed an algorithm and formulae to approximate the extent to which occupations will be automated in the next 10 to 20 years. They calculated automation probability using the formula:

$$P(y_* = 1 \mid f_*) = \frac{1}{1 + \exp(-f_*)}$$

Where for $f_* > 0$, $y_* = 1$ is more probable than $y_* = 0$. f can be thought of as a continuous-valued 'automatability' variable. The higher its value, the higher the probability of computerization. [5]

They used the U.S Department of Labor's O*Net data and obtained data for 702 occupations following the U.S Standard Occupation Classification codes. With the help of machine learning experts, they analyzed automation potentials for 70 occupations and their duties and came up with a model to determine the occupations risk of automation. These estimates were then used to approximate the automation potential for the remaining 632 occupations. [5] In the project "The Talented Mr. Robot", Brookfield Institute then applies the same methodology developed by Frey and Osborne to carry out a similar analysis for occupations in Canada using data from the NOC system. Their study reports that about 42% of the Canadian labor force is highly prone to being affected by automation; with about 18% of the jobs having at least 70% of activities that could be automatable in the near future. [10]

McKinsey and Company gauged the automation impact by developing a model for analyzing the work activities that are prone to automation. After collecting data and identifying about 2000 work activities relating to 800 US occupations, they analyzed these activities with regard to 18 key human competencies. Depending on the automatability of these activities they developed an estimate of the automation potential of the 18 human capabilities that the activities were respectively a part of. They reported that from their study about 60% of the occupations had at least 30% of activities that could be automated in the US. As such, occupations with activities least susceptible to automation lie in the fields of *management* and *expertise* while those highly susceptible lie in fields of collecting data, processing data and predictable physical work. The chart analyzing the automation potential of different human competencies is as shown below: [8]

Automation Capability		**Capability Level**	**Description**
Sensory perception	• Sensory perception		Autonomously infer and integrate complex external perception using sensors
Cognitive capabilities	• Recognizing known patterns/categories (supervised learning)		Recognize simple/complex known patterns and categories other than sensory perception
	• Generating novel patterns/ categories		Create and recognize new patterns/categories (e.g., hypothesized categories)
	• Logical reasoning/ problem solving		Solve problems in an organized way using contextual information and increasingly complex input variables other than optimization and planning
	• Optimization and planning		Optimize and plan for objective outcomes across various constraints
	• Creativity		Create diverse and novel ideas, or novel combinations of ideas
	• Information retrieval		Search and retrieve information from a large scale of sources (breadth, depth, and degree of integration)
	• Coordination with multiple agents		Interact with others, including humans, to coordinate group activity
	• Output articulation/ presentation		Deliver outputs/visualizations across a variety of mediums other than natural language
Natural language processing	• Natural language generation		Deliver messages in natural language, including nuanced human interaction and some quasi language (e.g., gestures)
	• Natural language understanding		Comprehend language, including nuanced human interaction
Social and emotional capabilities	• Social and emotional sensing		Identify social and emotional state
	• Social and emotional reasoning		Accurately draw conclusions about social and emotional state, and determine appropriate response/action
	• Social and emotional output		Produce emotionally appropriate output (e.g., speech, body language)
Physical capabilities	• Fine motor skills/dexterity		Manipulate objects with dexterity and sensitivity
	• Gross motor skills		Move objects with multidimensional motor skills

	• Navigation	Top Quartile (red)	Autonomously navigate in various environments
	• Mobility	Below Median (green)	Move within and across various environments and terrain

Where: [green] - Below Median [yellow] - Median [red] - Top Quartile

To develop a skill-based analysis in our study we analyzed the findings from these major studies. We then used data from Government of Canada career listings by essential skills [12], which provided information on the skills required in different occupations.

We analyzed these skills in relation to the 18 key human competencies, which had known automation potentials, to obtain an estimate of how prone the skills were to being automated. We then assess the educational requirement per occupation. This would enable us to see how occupations in different fields get affected and also provide an overview of the degree or faculties of higher educational institutions that are prone to being affected and possibly need improvements in their programs. For occupations with possibilities of having multiple educational background, we classified them as "Discipline may vary". From existing literature, we find statistics on the automation potentials of the occupations and the extent to which job activities will be affected. With the information from these data sets, we create an appendix to analyze the low-risk occupations in the industries. This provides different criteria from which the occupational and related skilled data could be viewed.

5. CONCLUSION.

In this paper, we see the major automation technologies and techniques being used today and how their applications are extending from routine to non-routine tasks with the help of statistics and big data. Major areas of human knowledge and skills that have been found to not be easily automatable are as follows. Although careers in STEM (science, technology, engineering and mathematics) fields are recommended to secure jobs in the industry, researchers further advise on the improvements of the basic skills involved in these fields. Skills such as *creativity* and *critical and systems thinking, agility, resilience,* and *flexibility* are predicted to have much more essence in the future because they symbolize the human advantage over machines. [8] Technical knowledge and expertise becomes important because as seen from the trends of the past, high skilled workers who work closely with technology will be in strong demand because of their technical know-how. Automation will create the opportunity for humans to emphasize on the innate human skills that machines cannot replicate like: *logical thinking and problem solving, social and emotional capabilities, providing expertise, coaching and developing others, and creativity*. Since automation is predicted to take care of the routine aspects of jobs, these skills will become highly demanded from workers. “Automation could make us more human.” [8]

In their research on occupational automation, Frey and Osborne find that there are three aspects of human nature that make them unique and hard to automate. These are: *perception and manipulation, creative intelligence* and *social intelligence.* They developed variables that were comprised of widely applied human skills that they described as Computerization Bottlenecks. These variables are regarded as bottlenecks to computerization because they involve the complexity in human skills. These skills are considered to have multiple “levels” or different degrees of application to perform different tasks which computer-controlled equipment cannot adapt to due to lack of actual understanding of the task it is performing. The skills are as shown:

Computerization bottleneck	O∗NET Variable	O∗NET Description
Perception and Manipulation	• Finger Dexterity	The ability to make precisely coordinated movements of the fingers of one or both hands to grasp, manipulate, or assemble very small objects.
	• Manual Dexterity	The ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate, or assemble objects.
	• Cramped Work Space, Awkward Positions	How often does this job require working in cramped work spaces that requires getting into awkward positions?
Creative Intelligence	• Originality	The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem.
	• Fine Arts	Knowledge of theory and techniques required to compose, produce, and perform works of music, dance, visual arts, drama, and sculpture.
Social Intelligence	• Social Perceptiveness	Being aware of others' reactions and understanding why they react as they do.
	• Negotiation	Bringing others together and trying to reconcile differences.
	• Persuasion	Persuading others to change their minds or behavior.
	• Assisting and Caring for Others	Providing personal assistance, medical attention, emotional support, or other personal care to others such as coworkers, customers, or patients.

In addition to this, the prior table on 18 key human competencies highlights some human capabilities that are safe from automation. Data from the Appendix in section 6 shows that skills in *Humanics* are key in performing tasks that are not automatable. Major examples of these skills are: *Teamwork, Entrepreneurship, Creativity, Ethics, Leadership* among many others that can be viewed from the appendix.

About 42% of the Canadian workforce is prone to being affected by automation; of which 18% of the labor force have at least 70% of their activities that could get automated. [10] As such, to cope with such technological advancements, workers have to further their expertise by gaining further education and cultivating such skills that are not susceptible to being automated.

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6. APPENDIX

Occupation	Key Skills	Educational Faculty	Proportion of automatable tasks (MGI)	Employed Canadian Labor, 2011	Automation Probability in next 10-20 years (Frey and Osborne)
Advertising, Marketing and Public Relation managers	Communication Creativity Analytical Negotiation Critical thinking Statistical Networking Multitasking Persuasive Diplomacy Commercial awareness	Business	**9.70%**	**56,220**	**2.30%**
Aerospace Engineers	Technical knowledge Creativity Problem solving Attention to detail Commercial awareness Communication Technical skills Time management	Engineering	**14.00%**	**6,010**	**1.70%**
Air pilots, flight engineers and flying instructors	Technical knowledge Spatial awareness Communication Teamwork Leadership Sustaining pressure Discipline Critical thinking	Aviation / engineering	**72.00%**	**15,635**	**18.00%**

Architects	IT skills Leadership Communication Judgement Technical ability Teamwork Commercial awareness Analysis and interpretation	Architecture	**11.00%**	**15,255**	**1.80%**
Banking, Credit and Investment managers	Accounting Accuracy Detail oriented Technical Computer Communication Customer service MS Office Commercial awareness	Business / Economics	**34.00%**	**73,450**	**6.90%**
Biologist and related scientists	Research Communication Observation Analytical ability Teamwork Ability to work independently Problem solving	Science	**42.00%**	**21,020**	**15.60%**
Chemical Engineers	Mathematical Project management Communication Leadership Teamwork Computer Attention to detail Commercial awareness Creativity	Engineering	**38.00%**	**11,400**	**1.70%**
Chemists	Communication Analysis Decision-making Problem solving Mathematical Technical skills	Science	**37.00%**	**15,450**	**10.00%**

Civil Engineers	Communication Leadership Project Management Technical skills Critical thinking Creativity Computer Problem solving	Engineering	**13.00%**	**50,340**	**1.90%**
Computer and infosystem managers	Technical and Computer Troubleshooting Problem solving Planning Data management Critical thinking Monitoring	Computer Science / Engineering	**19.00%**	**52,935**	**3.50%**
Computer Engineers (Except software engineers and designers)	Technical skills Communication Research Troubleshooting Decision-making Attention to detail Creativity Problem solving	Engineering	**25.00%**	**25,625**	**22.00%**
Construction managers	Organization Planning Teamwork Problem solving Communication Leadership Technical skills Time-management Project management	Discipline may vary	**17.00%**	**72,000**	**7.10%**
Corporate sales managers	Analytical Research Communication Computer Negotiation Leadership Planning	Business	**7.00%**	**80,045**	**1.30%**

Dentists	Manual dexterity Focus Communication Empathy Managerial ability Computer	Medicine	**23.00%**	**18,780**	**0.40%**
Economists and economic policy Researchers and analysts	Research Mathematics and statistics Communication Networking skills Organization Time management Accuracy IT skills	Economist	**13.50%**	**14,975**	**33.00%**
Electrical and electronics engineers	Creativity Computer Attention to detail Communication Leadership Teamwork Problem solving Mathematical Project management Leadership	Engineering	**41.00%**	**42,370**	**6.30%**
Engineering and Architecture Managers	Detail oriented Technical knowledge and skills Management - Projects, Risks and Labor Leadership Team work Decision making Communication Troubleshooting Problem solving	Engineering/ Architecture	**17.00%**	**25,295**	**1.70%**

Financial and Investment Analysts	Accounting Analysis Technical skills Communication Mathematical Planning Problem solving Tax Planning Critical thinking	Discipline may vary	**11.00%**	**37,245**	**23.00%**
Financial Managers	Accounting Accuracy Analytical Communication Entrepreneurial Interpersonal Mathematical Microsoft Office Time management	Discipline may vary	**34.00%**	**73,145**	**6.90%**
General practitioners and family physicians	Personal qualities Leadership Compassion Communication Time management Sustaining pressure Manual dexterity	Medicine	**31.00%**	**44,970**	**0.40%**
Government Managers	Organization Planning Negotiation Creativity Leadership Decision-making Teamwork Communication Interpersonal abilities Management - Projects, Time and Resources	Discipline may vary	**28.00%**	**25,785**	**25.00%**

Human Resource Managers	Communication Conflict resolution Management Decision Making Ethical Organization Administration Character judgment Customer service Decision making Computer MS Office Networking Team building Problem solving	Business	**14.00%**	**50,825**	**0.60%**
Information systems analysts and technicians	Programming skills Quick learning Teamwork Problem solving Interpersonal skills Communication Organization Business awareness IT skills Analytical Troubleshooting	Engineering	**38.00%**	**146,835**	**11.30%**
Journalists	Strong Communication Interest in current affairs Organization IT skills Self-confidence Research Presentation	Arts and media	**15.00%**	**13,280**	**11.00%**

Judges	Decision making Communication Listening Patience Just and impartiality Moral ethics Interpersonal skills Time management	Law	**21.00%**	**3,005**	**40.00%**
Lawyers and Quebec notaries	Commercial awareness Communication Attention to detail Time management Resilience and self-confidence Articulate and public speaking Academic ability Research Analysis	Law	**23.00%**	**80,515**	**3.50%**
Legislators	Advocacy Interpersonal Attention to detail Leadership Analytical Critical thinking Problem solving Litigation Research Client relations Teamwork Microsoft Office Written Communication Time management	Law	**4.00%**	**7,465**	**1.50%**

Mathematicians, staticians and actuaries	Mathematical Analytical skills Problem solving Statistical interpretation Communication Presentation Commercial Awareness Teamwork	Science	**13.30%**	**11,455**	**15.90%**
Mechanical Engineers	Analytical Computer Problem solving Creativity Communication Teamwork Mathematical Attention to detail Project management Troubleshooting Leadership	Engineering	**17.00%**	**47,095**	**1.10%**
Petroleum engineers	Technical ability Commercial awareness Analytical Creativity Project Management Teamwork Leadership Problem solving Computer	Engineering	**19.00%**	**9,315**	**16.00%**
Pharmacist	Teamwork Attention to detail Responsible Accuracy Analytical Listening Mathematical Problem solving	Pharmacy	**47.00%**	**32,190**	**1.20%**

Physicists and Astronomers	Mathematical Teaching skills Communication Research Problem solving Observation	Science	**9.50%**	**2,920**	**7.10%**
Professional Occupations in advertising, marketing and public relation	Research Analysis International perspective Time management Creativity Teamwork Networking Planning Communication Computer Public speaking	Discipline may vary	**13.00%**	**74,135**	**3.90%**
Professional Occupations in Business management	Decision making Communication Critical thinking Customer service Computer Negotiation Organization Problem solving Time management Teamwork	Discipline may vary	**3.00%**	**62,005**	**7.10%**
Purchasing Managers	Computer MS Office Mathematical Planning Product Management Financial Analysis	Business	**36.00%**	**14,870**	**3.00%**
Registered Nurses and registered psychiatric nurses	Personal Qualities Communication Empathy Sensitivity Interpersonal skills Teamwork Organization	Nursing studies/ Medicine	**29.00%**	**291,380**	**0.90%**

Retail and Wholesale trade managers	Innovative ability Communication Leadership Planning Analysis	Business	**28.00%**	**363,285**	**20.50%**
School principals and administrators of elementary and secondary education	Problem solving Communication Leadership Time-management Research	Discipline may vary	**15.50%**	**32,270**	**1.00%**
Senior managers - Governmental, Financial, Construction, Production, Transportation industries etc.	Analytical Planning Business & Labor Management Communication Problem solving Entrepreneurship Finance management Legal affairs Public speaking Teamwork Time management Microsoft Office Leadership	Discipline may vary	**24.00%**	**204,635**	**8.80%**
Supervisors (Various Occupations)	Communication Leadership Conflict Resolution Time management Critical thinking Observation Problem solving Interpersonal	Discipline may vary	**33.00%**	**13,810**	**1.60%**
University professors and lecturers	Expertise in specialization Communication Research Analysis Networking skills Organization Time management General IT skills	Discipline may vary	**9.20%**	**69,010**	**3.20%**

Web designers and developers	Creativity Detail oriented Analytical Technical knowledge IT skills Communication Problem solving Teamwork and collaboration	Computer science	**45.00%**	**22,740**	**21.00%**