ARTIFICIAL INTELLIGENCE IN CANADA

WHERE DO WE STAND?

INFORMATION AND COMMUNICATIONS TECHNOLOGY COUNCIL

APRIL, 2015

EXECUTIVE SUMMARY

Artificial Intelligence (AI) enables machines or the in-build software to behave like human beings which allows these devices to perceive, analyze data, reason, talk, make decisions and act. The advent of AI is leading to new technological advances and transforming the economic and employment opportunities for humans in a positive way.

AI-related technologies facilitate our lives with, for example, industrial robotics, robotic medical assistants, smart games, financial forecasting software, big data analysis algorithms in health and bioinformatics, pilotless cargo planes, drone ambulances, general purpose and workplace robots and others. The global economic impact of AI is expected to be between $7.1 trillion to $13.1 trillion by 2025, according to McKinsey & Company (*Disruptive Technologies: Advances that will transform life, business, and the global economy, May 2013*). Despite these huge strides in AI, a key question remains with respect to Canada's readiness to embrace the transformative nature of AI in an increasingly global and competitive environment. ICTC has conducted a research to understand the current ecosystem of AI in Canada and to raise awareness about the potential actions that can support its development and adoption.

The qualitative survey with industry and academia indicate that Canada should establish dedicated funding mechanisms for R&D, encourage graduate programs, and ease immigration for qualified students. It is important to encourage industry and academia collaboration by supporting targeted projects and to protect Canadian Intellectual Property (IP), and the innovations of small to medium size companies. Our consultation with stakeholders indicate that minimizing bureaucratic hurdles for tax credits, encouraging start-ups, and attracting international R&D companies to set up offices in Canada are critical for the expansion and adoption of AI.

In order to entice increased development of AI in Canada, public and private initiatives should offer access to capital and favorable financing options especially to micro and SMEs; increase the quality supply of AI talent through the educational system; provide knowledge hubs for SMEs to exchange best practices; and promote adoption of AI and related digital technologies in the business community.

ARE WE READY?

Despite these huge strides of AI, a key question remains with respect to Canada's readiness to embrace the transformative nature of AI in an increasingly global and competitive environment. ICTC's qualitative survey with industry and academia indicate that Canada should establish dedicated funding mechanisms for R&D, encourage graduate programs, and ease immigration for qualified students. It is important to encourage industry and academia collaboration by supporting targeted projects and to protect Canadian Intellectual Property (IP), and the innovations of small to medium size companies.

1. ARTIFICIAL INTELLIGENCE

Artificial intelligence (also known as computational intelligence) is defined as ***"the human-like intelligence exhibited by machines or software"***[1]. It is theorized that intelligence of humans can be described and intelligent machines or software can simulate it. These machines or software can reason, plan, learn, perceive and process information *like* human mind and thus ***facilitate*** human life. They can think and act for us, for example, clean, move objects, diagnose medical problems, provide care, write software, make the best weather predictions, compose music and play games with us. Artificial intelligence is an interdisciplinary field of study including computer science, neuroscience, psychology, linguistics and philosophy.

It is theorized that intelligence of humans can be described and intelligent machines or software can simulate it. These machines or software can reason, plan, learn, perceive and process information like human mind and thus facilitate human life.

Making intelligent machines, robots and software programs has been a central focus of scientific explorations and ICT industry inventions. Since 1950, AI research and developments have economically impacted many industries such as ***robotics, telecommunications, computer applications, health, finance, heavy industry, transportation, aviation, service industry, e-commerce, military, music*** and finally ***toys and games***. In fact, many ideas, systems and technologies have been developed in the world of AI, however, they are not called or considered AI products, rather they are mentioned with their specific names such as smart graphics, machine learning, e-commerce and so forth (i.e., this is called "*AI effect*")[2].

In 1970s, AI in Canada gained ground as an area of research and interest. For example a group of researchers at the Université de Montréal developed in early 70s a fully automatic machine learning program translating weather forecasts at Dorval Airport[3]. In 1982, the *Canadian Institute of Advanced Research* started to focus on AI and robotics and gathered researchers in Canada together. Today in universities all across Canada, there is AI, computer science and computational linguistics graduate programs. In the global context, there is resurgence and new industrial applications compose technologically revolutionary components of digital economies.

2. INFLUENCE ON THE DIGITAL ECONOMY

AI is not a field in and of itself; rather it is a heterogeneous mixture of research fields. Hence, it is difficult to describe the influence of a well-defined or single field on economy. However, AI-related industrial applications produce the cutting-edge technologies that rapidly transform every aspect of our lives. In coming decades, AI-related industrial applications will replace most human power in fields including call centers, customer services and air cargo transportation[4]. AI technologies help weather forecasting based on repeated rainfall pattern (data) recognition, tackling boring and repetitive tasks

through robotics (i.e., floor cleaning, mowing lawns etc.), transporting people and goods with unmanned vehicles, sending space unmanned smart shuttles, developing robotic arms, predict market values in stock exchanges, making homes safer, help elderly and disabled using robotic servants and so on[5].

Among the AI-related technologies, there are a few that have significance for the impact on society and especially on digital economy. As a heterogeneous field, AI is particularly influential in ***machine learning, robotics, transportation, finance, health and bioinformatics, e-commerce, games, big data and internet-of-things.*** It is also important to note that there is a functional overlap between these fields, for example machine learning is used in bioinformatics and robots that can learn new skills for better caregiving in healthcare. Below is a summary of above AI-related technologies that are socially transformative and economically powerful.

Machine Learning: Machines can learn from data, come up with generalizations and make decisions to act in certain ways. There are important applications such as machine perception, natural language processing, search engines, bioinformatics, brain-computer interface, game playing, robot locomotion, advertising, computational finance, health monitoring, DNA classification and decision making in chemistry-cheminformatics. Machine Learning can positively impact productivity and can enhance information and analytical systems. To that end, *Alberta Innovates Center for Machine Learning*[6] helps Alberta companies to make them more competitive through the application of Machine Learning.

Robotics: Robotics is one of the most strongly influenced fields in AI. For heavy industries, for example, robots are used and human power is replaced for effectiveness, precision and accuracy, especially in repetitive or dangerous tasks, including welding, painting, assembly, picking and placing. Applying machine learning techniques, more intelligent/autonomous robots can acquire new skills or adapt the changing/dynamic environment, and thus they can move, play tennis, recognize and grasp objects etc. Highly autonomous robots can be functional in, for example, space exploration and cleaning[7].

MACHINES CAN DO IT!

Machines can learn from data, come up with generalizations and make decisions to act in certain ways. There are important applications such as machine perception, natural language processing, search engines, bioinformatics, brain-computer interface, game playing, robot locomotion, advertising, computational finance, health monitoring, DNA classification and decision making in chemistry-cheminformatics.

Transportation: Artificial intelligence can be applied in developing, for example, automated vehicles, driver assistance systems, safety systems, collision avoidance systems, and public transportation. Given the sustainability problem of individual transportation, developments in especially intelligent public transformation will be valuable in coming decades[8]. According to The

American Federal Aviation Administration predictions, unmanned aircrafts will transport, in about forty years, approximately 40% of air cargo[9].

Finance: AI technologies have proven to produce some of the best tools to predict stock market fluctuations. AI market predictions are based on ever-evolving predictor algorithms and these systems learn new models and make connections between historical data and new data[10]. It is believed that AI technology will produce in future more accurate and functional tools with non-linear decision making logical models and thus will revolutionize stock market trading.

Health informatics: AI is used in health field, especially in health data processing, analysis, decision support and medical diagnosis. Massive amount of health data is collected and when it is properly analyzed by intelligent software, the data shows which patients will need what treatment and what alternative drugs could be used[11]. AI systems can outperform doctors, although they are not intended to replace doctors, they can work alongside doctors in order to increase the quality of care[12].

Bioinformatics: Bioinformatics is an interdisciplinary field combining statistics, mathematics and engineering in order to organize and analyze biological data, especially in molecular biology. AI helps in discovering data patterns and modeling through the application of machine learning, artificial neural networks and genetic algorithms[13]. For example, *Human Genome Project* uses bioinformatics techniques to analyze billions of data sequences.

E-commerce: Online shopping can be facilitated by virtual assistants developed through AI technology, and these assistants can offer the best advice. Purchases coming after product recommendations and personalization bring important revenue (35%) to shopping sites like Amazon[14].

AI offers technology and methodology and thus enables big data to provide industrial organizations with valuable information for effective decision making. The smart machines powered by AI software can crunch past data and find out patterns, just like what IBM's Watson achieved: this machine used 200 million pages of structured and unstructured content with a special technology of hypothesis generation, massive evidence gathering, analysis, and scoring.

Smart computer graphics and games: Artificial intelligence is useful in smart computer graphics, scene modeling, scene rendering processes in order to create, for example, effective human-robot interactions. Other techniques that are directly related with AI are also used in computer graphics; these are machine learning, strategy games techniques and other techniques[15]. One assumption supporting this AI work in smart graphics is the idea that "the mind can be modelled through the adequate combination of interacting, functional machines, or modules"[16]. According to *Microsoft Research*, video games can be more realistic, virtual creatures can exhibit intelligent behaviors, and game environments can be realistically complex. Game software can learn, search and plan, and thus offer a better game experience in an intelligent world[17].

Big data: All of the fields mentioned above use big data analysis and big data does have a critical place in the world of intelligent machines and software. In other words, AI offers technology and methodology and thus enables big data to provide industrial organizations with valuable information for effective decision making. The smart machines powered by AI software can crunch past data and find out patterns, just like what *IBM's Watson* achieved: this machine used 200 million pages of structured and unstructured content with a special technology of hypothesis generation, massive evidence gathering, analysis, and scoring.[18] Hence some argue big data is the ground for new AI[19]. In fact, *European Commission* offered in 2013 a number of critical policy suggestions in order to *increase the impact of AI technologies on Big Data*[20].

Internet-of-Things: Internet of things (IoT) is the network of machines or objects connected through internet. These connected objects can sense their internal or external environment, communicate with each other, send critical data and finally make decisions to act or correct their environment. For example, factories can monitor and automatically change production processes; hospitals can monitor and regulate the health conditions of their patients; schools can collect data from the facilities; and cars can send data to car makers. *Gartner* predicts that IoT market will create about $1.9 trillion value by 2020[21]. Although machines collect Big Data from their environment, whether they gain an *insight* or *learn* from these data largely depends on the machine learning principals and AI technologies: In short, IoT will not work without AI technologies [22].

3. ECONOMIC IMPACT OF AI IN THE WORLD

In 2013, McKinsey estimated that the disruptive technologies closely related with artificial intelligence might have a potential economic impact in 2025 between $7.1 to $13.1 trillion (automation of knowledge work, advanced robotics, autonomous or near-autonomous vehicles)[23]. *International Federation of Robotics* reported that spending on robotics was $7.4 billion in 2000, $15.1 billion in 2010, and it is predicted to reach $66.9 billion in 2025[24]. Global medical robotic systems market is expected to reach $13.6 billion in 2018, more than double of 2011 level ($5.48 billion)[25]. In the USA, integration of *Unmanned Aircraft Systems* will have an $82 billion cumulative economic impact between 2015 and 2025; and total job creation will reach 104,000[26]. *European Commission* published an important case study and predicted that AI market will exceed 27 billion Euro by 2015, which was only 0.7 billion in 2013[20]. The economic trend is clear and AI-related technologies play a critical role in growth. It is, however, important to note that there is no information on the impact of AI on GDP and employment in Canada; and economically AI is a hard space to define.

In 2013, McKinsey estimated that the disruptive technologies closely related with artificial intelligence might have a potential global economic impact in 2025 between $7.1 to $13.1 trillion (automation of knowledge work, advanced robotics, autonomous or near-autonomous vehicles).

4. CHALLENGES IN CANADA

Given the importance of AI in industry and growing digital economy, it has been important for ICTC to further investigate the AI ecosystem in Canada, including industrial and educational context. ICTC therefore conducted a brief qualitative survey with 11 industry and academia members, to gather their insights around some of the critical questions and findings from their responses have been summarized below:

i) What are the AI human resources issues in Canada?
Participants raised significant concern on the *lack of available graduate students*, *restrictive immigration policies on visa students*. Further, *lack of sufficient demand from industry* for the AI expertise prevents *retention of highly-qualified people in Canada* who are drawn by the competition for talent from USA. Despite having some excellent graduate programs here in Canada, industry capacity is limited.

ii) Are there enough funds available in Canada for Research & Development purposes?
Respondents clearly indicated "no" and expressed concerns with *lack of funding* for the industrial research. Receiving grant funding for R&D or even receiving tax credits come with certain *bureaucratic hurdles*. In the case of universities, some believe there is not enough research funding. As a downward trend, universities tend to scale back their interest and commitment to AI research, especially in the absence of industry capacity.

Without considering the critical economic impact of AI, funding targeted projects and research, easing immigration of qualified students, removing bureaucratic hurdles for tax credits, creating an entrepreneurial environment, inspiring start-ups and protecting Canadian IP, it is a question how Canada will be able to keep up with speed of AI-related economic transformations.

iii) What is the economic impact of AI in Canada? In what ways AI influences Canadian economy? Although the impact of AI on the Canadian economy is unclear, there are many companies that should be using AI technologies but are not using it; and there many other companies using AI technologies without being aware of it, as these technologies are not known as "AI technologies". There are *start-up companies that move to the US,* because industry is not receptive in Canada. Benefits of the world-leading academic research produced in Canada *are reaped in the US* (e.g., neural networks). AI is expected to have an extraordinary impact in the developed countries that depend on knowledge resources, however, the impact in Canada is expected to be moderate due to *dependence and reliance on natural resources*. AI indirectly influences competitiveness of Canadian economy by being embedded in various industrial products.

iv) What are the consequences if Canada doesn't produce enough AI technologies? Are there any cost-benefit differences between Canadian produced AI versus imported AI?

AI is an *important industrial factor* and it will soon be ubiquitous; hence Canada should gain competitive advantage. Return on Investment (ROI) is very high in AI fields and instead of buying it from elsewhere, Canada should produce AI technologies and compete in the global industrial market. Although Canadian academics are *world class researchers,* some of them *move to other countries with stronger AI industry and research*, and thus Canadians *lose competitive advantages*. AI creates value-added products and *contributes to the knowledge-based economy*. As a positive result, AI fields can *help Canadians get away from the dependence on resource sector*.

v) What could governments do for the future of AI in Canada? Considering the AI developments across the world (for both users and developers), what are your recommendations for Canada?

There are four groups of recommendations: First, respondents mentioned establishing dedicated *funding* for R&D, encouraging specialized graduate programs, making science a national priority and *easing immigration* strictures for qualified students. Second, it is important to encourage academics to develop technologies to meet industry needs and it is important to *fund joint industry-academia projects*. However, when governments set priorities for industry, knowledge transfer from lab to industry slows down. Rather than giving broad support to AI, targeting specific promising projects can be more productive. Third, respondents pointed the importance of *protecting Canadian IP* and innovations of small to medium size companies. It is also important to *encourage AI-related industries to set up offices in Canada* in order to do more R&D (e.g., Google, Yahoo, Microsoft, Amazon etc.). Fourth, organizing symposia, roundtable discussions and workshops, establishing a center of excellence might be fruitful for the age of artificial intelligence. Due to size and population density of country, *governments should foster synergy* and communications among Canadians working in similar AI fields.

5. CONCLUSION: CALL TO ACTION FOR THE FUTURE OF AI IN CANADA

Economic and social benefits of a powerful AI industry are immense. AI technologies are creating a critical impact on a number digital economy fields. The cumulative economic impact of AI in 2025 is predicted to be between $7.1 to $13.1 trillion; the trend is currently evident and the impact of AI on GDP and employment in Canada remains to be explored. Considering this impact, Canada needs to have strategies in place to keep up with the speed of AI-related economic transformations. Strategies can include targeted funding and research, easing immigration of qualified students, removing bureaucratic hurdles for tax credits, creating an entrepreneurial environment, inspiring start-ups and protecting Canadian IP.

While there are many catalysts to AI development and adoption, two main challenges in front of a strong AI economy are financing and talent sources. In order to develop AI-related technologies and to increase AI adoption in Canada, public and private initiatives need to increase especially for micro and SMEs the access to capital and introduce favorable financing for AI development and adoption; increase the potential for industry upskilling through financial incentives; increase the supply of AI talent in Canada through the educational system as early as schools; provide knowledge hubs for SMEs to exchange best practices; and finally promote the adoption of digital and AI technologies in the business community. ICTC has initiated a digital adoption hub for SMEs where business leaders learn about new technologies, explore funding opportunities and share best practices. Development and adoption of AI technologies should be promoted in similar ways. ICTC calls industry, academia and policy makers to action in order to plan the future of AI ecosystem in Canada.

ENDNOTES

[1] Artificial_intelligence, Wikipedia
[2] AI_effect, Wikipedia
[3] The Canadian Encyclopedia, Artificial Intelligence, Zenon W. Pylyshyn, 15, December, 2013
[4] Artificial intelligence 'will take the place of humans within five years', The Telegraph, Rebecca Burn-Callander, 29 Aug 2013
[5] 10 Ways Artificial Intelligence Will Affect Our Lives, Discovery.com
[6] Alberta Innovates Centre for Machine Learning
[7] Autonomous_robot, Wikipedia
[8] AITS - Artificial Intelligence in Transportation Systems, EPIA 2013
[9] Factsheet 1: Civil unmanned cargo aircraft, Platform Unmanned Cargo Aircraft
[10] Artificial Intelligence: the Future of Stock Market Trading, Kscripts, December 2013
[11] Artificial Intelligence Is Now Telling Doctors How to Treat You, Daniela Hernandez, Kaiser Health News, 06.02.14, Wired
[12] How Artificial Intelligence Could Improve Health Care, Taylor Killough, January 25, 2014, Indiana Public Media
[13] Artificial Intelligence Techniques for Bioinformatics, A. Narayanan , E. C. Keedwell , B. Olsson , A. Narayanan , E. C. Keedwell , B. Olsson, Cite Seer X
[14] Transforming E-Commerce: The Introduction of Artificial Intelligence, Martin Rugfelt - November 19, 2013, Retail Info Systems News
[15] Using Artificial Intelligence Techniques in Computer Graphics, Dimitri Plemenos, International Conference Graphicon 1999, Moscow, Russia
[16] Artificial Intelligence in Computer Graphics: A Constructionist Approach, Kristinn R.Thórisson, Christopher Pennock, Thor List,John DiPirro, Communicative Machines Labs, February 2004
[17] Video Games and Artificial Intelligence, Microsoft Research
[18] Watson_(computer), Wikipedia
[19] Big Data is the new Artificial Intelligence, Robert X. Cringely, Beta News
[20] Big Data: Artificial Intelligence, Business Innovation Observator, European Union, September 2013
[21] Gartner Says Personal Worlds and the Internet of Everything Are Colliding to Create New Markets, November 2013, Gartner.
[22] IoT Won't Work Without Artificial Intelligence
[23] Disruptive technologies: Advances that will transform life, business, and the global economy, May 2013, McKinsey&Company
[24] The Rise of Robotics, Alison Sander and Meldon Wolfgang, August 27, 2014, BCG Perspectives
[25] 5 areas in Robotics that will transform society and their economic impact, Colin Lewis, April 23, 2014, RobotEnomics
[26] The Economic Impact Of Unmanned Aircraft Systems Integration In The United States, AUVSI, March 2013