◆ 論　文

Changes in Society and Conversion of Industrial Structures through the Fourth Industrial Revolution

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keyword | Technological breakthrough; Singularity; Artificial Intelligence; Moravec's paradox

Ⅰ. Introduction

Japan and the world have been in the midst of upheaval economically and socially. The expected roles of science and technology are drastically changing in those circumstances. This paper attempts to explore the influence of technological changes on society. The fourth industrial revolution is evolving at an exponential rather than linear pace. How do companies adapt to discontinuous technological change?

AlphaGo is an artificial intelligence developed by Google DeepMind in London, which has beaten a professional human Go player for the first time. AlphaGo's algorithm utilizes a Monte Carlo tree search in order to find the most effective moves based on knowledge previously "learned" by machine learning, specifically by an artificial neural network (a deep learning method) through extensive training, both from human and computer play. Although it used to be seem difficult that any computer program would beat a professional player in complecated games, now that artifiial inteligence is able to win human professional players even in Go, which is one of the most complecated board game for computers. These incredible technological changes will definitely spread in our society. Deep learning is emerging machine learning technology based on a set of algorithms that attempt to model high level abstractions in data by using a deep graph with multiple processing layers, composed of multiple linear and non-linear transformations.

Science and technology is now developing dramatically and with more impacts than ever before in a wide-ranging fields, such as IoT, big data, robots, and artificial intelligence (AI). These changes have a huge potential of economic impact which will drive truly massive economic transformations and create value network that will eventually replace existing products. Our examination will contribute to figuring out the nature of technology, which affects global competitive position. The special topics in product management are IoT and AI. Emerging technologies such as Robot revolution, Hydrogen society, Aerospace and IoT will alter the business or social landscape. Huge technological system is composed of wide range of elemental technologies. These technologies are connecting with each other.

Science and technology are expected to lead to the solution of global-scale problems like natural disasters, and heating up competition of natural resources, water, energy and food.This study empirically analyzes technological changes, based on research at innovative companies challenging advanced actions and research institutions like NEDO, AIST, RIKEN, NIMS, JAXA, KEK, JST, and so on.

Ⅱ. Background and Significance

Emerging technological breakthroughs, such as machine learning, robotics, and internet of things (IoT) are driving technological explosion and is changing people's lives for the better. Kurzweil (2005) said, “The key idea underlying the impending Singularity is that the pace of change of our human-created technology is accelerating and its powers are expanding at an exponential pace.”

Human errors have been serious issues in various field. However the accuracy of image recognition has increased dramatically thanks to the deep learning technology, and now the accuracy is higher than image recognition by humans. For example, performance of image analysis systems are evolving drastically that support to improve quality and increase productivity based on detecting signs of operational failures in production line facilities and deviation in worker activities on the front lines of manufacturing. At the same time, it's spreading in more and more highly specialized fields such as audit, legal or medical treatment. Thus, we should focus more on human intention or engineering ethics, not in technology itself because the technology can do harm to humans if they are abused.

Moravec (1988) has observed, “It is comparatively easy to make computers exhibit adult-level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility.” This situation is called Moravec's paradox.

A research group at NIMS created an unprecedented highly efficient method for developing friction materials with a desired frictional property. Technology for freely controlling the friction coefficient of a material is a vital factor for development of low-friction materials for reducing energy loss and high-friction materials required for high-performance brakes. These new technologies are drawing attention in association with global environment and energy issues[i].

Using Artificial Intelligence, some companies have developed and launched technology to automatically create effective advice which helps executives to resolve corporate management issues they are facing, through collecting the massive amount of data. Moreover, these technology is spreading in various industries and workplaces, for example, Hitachi has developed technology to create effective advice to increase worker happiness using artificial intelligence, aiming at increasing worker's productivity[ii]. JAXA is operating Space Transportation System “Epsilon” Launch Vehicle. JAXA is not only thinking about cost reductions but also aiming at lowering handles to space by developing a space transportation system suitable for a new age and by making rocket launches much simpler. JAXA plans to improve the operation performance to the highest global standard by utilizing innovative ideas far beyond a simple combination of existing technologies. JAXA will make the vehicle perform checks onboard and autonomously and reduce the time required for operations on the ground. Ultimately, through internet, JAXA will be able to check and control rockets anywhere in the world simply by using a laptop computer[iii].

Davenport (2016) states that "If work can be codified, it can be automated. And there's also the corollary: If it can be automated in an economical fashion, it will be. Already we're seeing a rapid decomposition of jobs and automation of the most codifiable parts—which are sometimes the parts that have required the greatest education and experience."

Ⅲ. The worldwide increase in population and the pressure for economic growth

According to World Population Prospects the 2015 revision by United Nations, median estimate shows the total amount of world population will be over 10 billion by 2083, and it is expected that this rapid increase of world population will increase severe competitions for water, natural resources and food. Science and technology is a driving force for accelerating economic growth and solving global scale issue. Kurzweil (2005) predicts the singularity to occur around 2045, which is triggering progress and change in the mode of human life.

There are some next-generation products that do achieve reduced CO_2 emissions while they are used, but actually they also cause increased CO_2 emissions at the material and production stages, which is known as a paradox of "eco-friendly" products. Although some super computers are consuming incredible amounts of energy, K, a super computer produced in Japan places sixth in the GREEN500 energy efficiency ranking in June, 2011, as all of its components are designed for high energy efficiency[iv].

Like Smart Phone, Smart Grid, Smart Construction, Smart Factory, Smart Agriculture, Smart Home, Smart TV, we have seen more and more products prefixed "Smart" in our daily lives. Smart Sensor, in other words, Intelligent Sensor is a sensor with abilities of analyzing and computing information. They measure the objects with multiple sensors and collect multiple in-

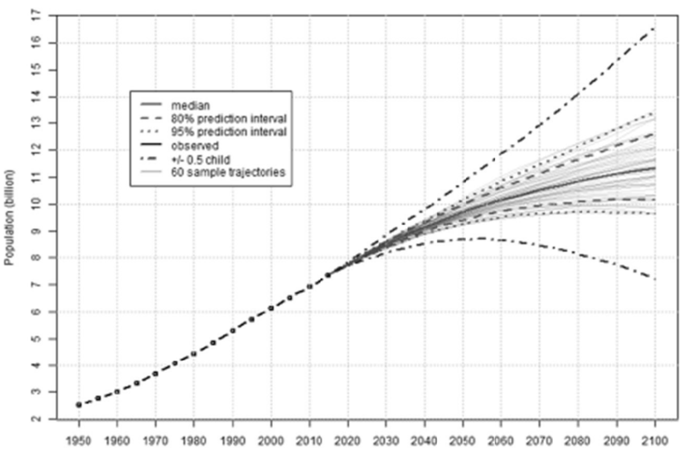

Figure 1. World: Total Population

Source: United Nations, Department of Economics and Social Affairs, Population Division (2015), World Population prospects: The 2015 Revision formation at the same time, process and accumulate the outputs, while eliminating outliers. In other words, they have automatic calibration function and automatic compensation function.

In these situations I mentioned above, can we stick to the previous business models based on previous technologies and success stories? According to World Economic Forum's "The Future of Jobs", by the year 2020, technological changes will have a profound impact on the employment landscape. This impact might lead to more than 5.1 million jobs loss with a total loss of 7.1 million jobs and 2 million jobs gain.

Ⅳ. The radical changes towards the fourth industrial revolution

New technologies are now advancing drastically and with more impact than ever before in a variety of fields, such as IoT, big data, robots, and artificial intelligence (AI).

The word "robot" was proposed by Karel Čapek via Czech play, "R.U.R (Rossum's Universal Robots)" in 1920.

Isaac Asimov provided three laws of Roboticss[V]:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given to it by human beings, except where such orders

Figure 2. Net employment outlook by job family, 2015-2020

Source: World Economic Forum (2016), *The Future of Jobs-employment, skills, and workforce Strategy for Fourth Industrial Revolution-, executive summary,* January, 2016.

would conflict with the First Law.

3．A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

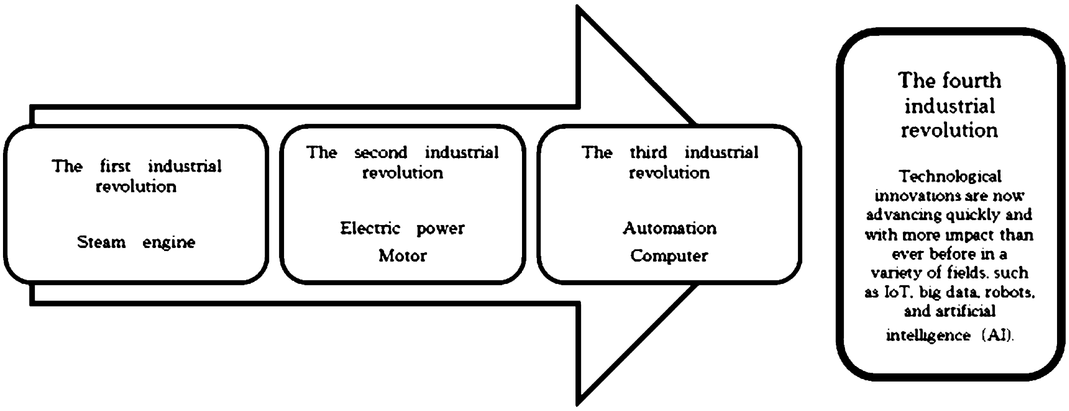

Figure 3. Towards the fourth industrial revolution

Source: METI, the New Industrial Structure Vision (An Interim Report on New Industrial Structure Vision), 2016/04/27.

Japanese companies need to change industrial technology. The Ministry of Economy, Trade and Industry (METI) aims to formulate a policy titled “Future Vision of Innovative Industrial Structures”.

An interim report on the New Industrial Structure Vision was compiled in April[vi]. Towards the fourth industrial revolution, especially in manufacturing industry, latest technologies are being connected with each other and utilized not only to increase productivity drastically but also to innovate business model through the whole of the supply chain.

Rifkin (2015) comments that “We are, it appears, in the early stages of a game-changing transformation in economic paradigms. A new economic model is emerging in the twilight of the capitalist era that is better suited to organize a society in which more and more goods and service are nearly free.” Intelligent infrastructure-the Internet of Things (IoT) -is already boosting productivity to the point where the marginal cost of producing many goods and service is nearly zero.

With its birthrates declining and its populating aging, Japan has experienced a long period of stagnation. The next step in the evolutionary process of collaboration between humans and robots is trying to release workers from unskilled labor or working under severe labor environment by automation. Brynjolfsson (2014) illustrates that “If the first machine age helped unlock the forces of energy trapped in chemical bonds to reshape the physical world, the real promise of the second machine age is to help unleash the power of human ingenuity.

Ⅴ．Analysis of the technological change

Since we are facing these radical changes, the Japanese companies should strengthen interdisciplinary Science and Technology.

Our study specifically focuses on the three phases of technological progress, assuming that there are three phases of technological development and transitions. In the first phase, the initial focuses are on fine adjustment, trial and errors and experience of each person. Japanese companies tended to rely too much on technical solutions which were produced by trial and errors of a skilled workers.

On the other hand, in the second phase, more attentions have been paid for simulation and analytical evaluation. Moreover, in the third phase, artificial intelligence has huge potentials to change the industry itself for the better, for instance, it may enable us to overcome Moravec's paradox.

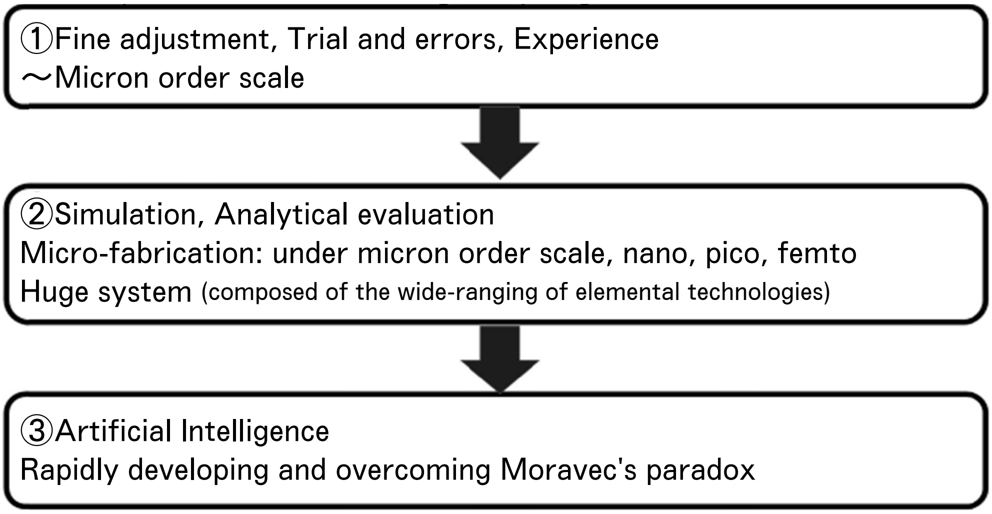

Figure 4. Three phases of technological progress

Contrary to the first and second phases, the latest change is evolving at exponential pace rather than linear one. The radical change has a more profound effect on existing business, furthermore civil society. It is not possible to clarify whether the situation might get even better or worse.

Although fine adjustment, and trial and error based on skilled workers' experience still do matter, simulation and analytical evaluation will can improve productivity much more, regarding ensuring accuracy and securing high quality and reliability under micron order scale. These are some simulation or observing systems in practical use in Japan, such as K computer (RIKEN[vii]) and Earth Simulator (JAMSTEC) for simulation and analytical evaluation, and SACLA (X-ray Free Electron Laser: XFEL), Spring-8 (Super Photon Ring-8Gev), J-PARC for Observing and examining microstructures at the atomic and molecular level by using leaving simulation and analytical evaluation on them. The robots imitating human's motions and overcoming human errors come into practical use now thanks to today's technological breakthroughs.

Industrial-government-academic collaboration for innovation have increased their cooperation by utilizing systems such as "research & development partnership (technology research associations)". A new journal entitled "Synthesiology" is published by the National institute of Advanced Industrial Science and Technology (AIST). The National institute of Advanced Industrial Science and Technology was founded in 2001 by the integration of 15 research institutes under the Agency of Industrial Science and Technology. It is a multidisciplinary institute covering wide-ranging fields including mechanical engineering, electricity, electronics, materials, chemistry, life science, information science, energy, environment, geology, and metrology. "Synthesiology" is aiming at utilizing the fruits of research for social prosperity. There is a wide gap between scientific achievement and its utilization by society that has been called "the valley of death", or "the nightmare stage"[viii].

Brynjolfsson (2014) states that "Computers and other digital advances are doing for mental power—the ability to use our brains to understand and shape our environments—what the steam engine and its descendants did for muscle power. We're at an inflection point—a point where the curves starts to blend a lot—because of computers". Our generation will likely have the good fortune to experience two of the most amazing events in history: creation of true machine intelligence and the connection of all humans via a common digital network, transforming the planet's economics.

Davenport (2016) investigates "augmentation". Automation and augmentation might sound like two sides of the same coin. "Automation" means using machines to do what humans would otherwise do, and therefore do without the humans. Because of these reason, workers love "augmentation", on the other hand, they hate "automation", so it is reasonable to assume that the difference between them is not just rhetorical.

Ⅵ Discussion and conclusion towards realization of sustainability

This paper described the three phases of technological progress that might be complicated and enormously speeding up than assumed. It has become obvious that AI machines' power evolves at an exponential pace, it may enable us to overcome Moravec's paradox which suggests difficulties of perception and mobility equal level to an one-year-old infant, compared with the fact that computer can perform well on intelligence tests or playing checkers as high level as human adults.

As exemplified by the arguments above, the issue of radical technological change has left the realm of manufacturing and become a matter of great significance on a global scale.

Davenport (2016) illustrates, "We know there are very real downsides to the new wave of smart machines, but the upside potential of the advancing technology is the promise of *augmentation*—in which humans and computers combine their strengths to achieve more favorable outcomes than either could alone. Japan and the world are suffering from unprecedented changes and need to achieve sustainable growth and societal development into the future and science and technology are expected to lead to the solution of global-scale problems.

President Obama said in Hiroshima, "Technological progress without an equivalent progress in human institutions can doom us". Brynjolfsson (2014) writes that "Our era will face other challenges, ones that are not rooted in economics. The technologies we are creating provide vastly more power to change the world, but with that power comes greater responsibility.

Although these overall negative effects of technological change are outside the scope of this paper, it will be valuable to conduct a further investigation into them.

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Notes

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