2014

White Paper on Robotization of Industry, Business and Our Life

When you try to change society,
robotics technology will be there!

NEDO

New Energy and Industrial Technology
Development Organization

In Editing the White Paper on Robotization of Industry, Business and Our Life

It can be said that 'robotics technology' has reached a turning point in recent years.

Certainly, robots commonly covered by the media give rise to dreams and are usually introduced as the protagonist in causing us to forecast the future. We also loosely picture bipedal walking robots like in movies, coexisting with us peacefully in the realms of our everyday lives. In addition, we view speedily accurate, silent and skilled industrial robots as reliable machines, as if they symbolize Japan's competitive power.

However, as robotics technologies evolve around the word, gradually within robotics manufacturers we are recognizing things such as what robots could accomplish practically, what we must make them accomplish practically, and what they might accomplish practically that might not be easily accepted by society.

For example, if a large company with sales at the trillion yen scale continues to sell a number of robots at X yen per robot with a specific target audience, can we maintain that large organization's business? Also, will replacing humans with those sorts of robots have enough value to make people want machines to replace humans? Robots being accepted into society means that they will be used by men and women, both young and old, but will safety and so on be acceptable? We have run into these realistic challenges as if waking from a dream.

Hereafter, with robots supporting our livelihoods as a truly necessary partner-like existence in society, we will focus on continuing to be an industry that represents a technologically-driven Japan. With many specialist books and magazines already being published in the world, we have reconsidered the various themes surrounding robotics, sorted the outlooks of the future and the state we need to aim for, and edited this book in order for all citizens to understand.

This book, as with many other specialist books, has been organized into categories and chapters such as ‘Industrial Robots’ and ‘Service Robots’ based on the robots’ application, structure, etc. However, because the expected functions and roles, challenges produced, and direction of future advancement is different for each robot, there are differences in the formatting approaches and descriptions in each chapter, and each one contains a message which is characteristic to it.

In order to keep this book from simply becoming a handbook for and by robotics experts, we have left the more particular details for specialist books, and a wide group from specialists to everyday people and students will be able to grasp the entirety of robotics technology when they read this book. This book also aims to be a bridge for people wanting to create a new business, and aims to inform them of robotics technologies that could be the means for solving the challenges they will deal with. Last of all, this book aims to contribute to the stimulation of the robotics industry.

Contained within this book is a passionate message from the editorial board; “When you try to change society, robotics technology will be there!” We would be pleased if those reading this book not only conceptualized new business opportunities using robotics technology, but also contributed to the strengthening of the development and competitive power of Japan's robotics industry.

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Mechanical System Group
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Contents

The 2014 'White Paper on Robotization of Industry, Business and Our Life' is titled "When you try to change society, robotics will be there!" and talks about the highly anticipated robotics field market and the domestic and international technological movements as an introductory example of 'Robotics Technology' (RT). Robotics technology has become closely associated with the daily lives of people and society as well as for being a provider of the industry's competitive strength. Chapter 1 explains the basics of robotics. Chapter 2 summarizes the significance, necessity and surrounding environment of robotics applications from many perspectives. Chapter 3 follows the changes in Japan's manufacturing industry and how manufacturing industry robots will develop while talking about the analysis of the current challenges for the robotics industry and the hopes for the future. Chapter 4 presents lifestyle and service field robotization industries and talks about specific examples of industries which have incorporated 'robotization' amongst industries which provide those products and services. Chapter 5 discusses field robotics while focusing on economic improvement, hazard aversion, and the creation of a new society, and from there, considerations so that we can develop with thought towards many fields. Chapter 6, unlike chapters 1 to 5, is not a forecast style discussion of current technology. It paints a futuristic vision of what should happen in the future and discusses the technology which will be required for it in a backcast fashion. A summary of chapters 1 to 6 in the 2014 'White Paper on Robotization of Industry, Business and Our Life' is given below.

1. ABOUT ROBOTICS

1.1. Summary

This chapter explains the basics of robotics. Specifically, it presents the definition of robots and robotics technology, the history of robotics, elements of robotics and representative examples of robotics. The matters written here are general matters at the present time, and the following chapters talk about future development.

Firstly, the definition of robots and robotics technology here is compared with the general goal of this white paper and is not simply academic or technical, which is to say it is not just about how to make robots or robotic systems, but is devised to focus on how robots and robotics technologies will be used, their industrial and societal role, future development and other similar topics as well.

Specifically, **"This white paper defines robots and robotics technology—in considering robotic and robotized equipment as systems with incorporated robotics and robotics technologies that do not contradict the Robot Policy Research Society's definition—as the progression of information exchange and collaborative activity of people interested in robots which will further develop subjects and thus lead to developments in: productization, industrialization, and commercialization; engineering production and production of applicable objects expected to lead to societal implementations including to the public sector; and core technologies affecting use in all fields that can create value by being robotized in the service industry field as well as the manufacturing industry field."** From this, we believe the applicative developments of robots and robotics technology—the aim of this white paper—can be read with many interpretations.

The history of robotics is emphasized by the milestones denoted in this book. It is appropriate to consider automata and mechanisms as the origin of robots from an engineering viewpoint, and the key topics of development following those are:

- 1778 Steam engine speed control (Watt)
- 1948 N. Wiener ‘Cybernetics’
- 1954 G. Devol ‘Programmable Transport Machine’
- 1958 Shannon & Minsky ‘Manipulator’
- 1961 Ernst ‘Manipulator’ for practical use
- 1962 Industrial robots ‘Unimate’ and ‘Versatran’
- 1971 Microcomputer

Having many similarities with computers is characteristic of the development of robotics technology. Namely, computers started from machines performing calculations, and through developments in semiconductor technology and computer technology its scope of use expanded as a controller. It was then networked and has now penetrated society as a system which substitutes and strengthens knowledge and information processing. Robots started as replacements for human labor as well, but by integrating vision and other similar identification technologies for work objects they have developed into humanoid robots. Furthermore, robotics has progressed from a world of building blocks like during the early stages of artificial intelligence and have moved on to ‘real world computing,’ which targets the real world. Specifically, it hones the sublimation of RT technology with no regard to appearance as a complementary expansion for human ability, and raises hopes for the removal of barriers in Japan's currently extremely aged society. Major points include:

- An even larger impact than IT
- Embedded RT
- Ubiquitous RT, decentralized contribution via networking
- Openness, interoperability, information reusability
- Externalization of the brain via computers + externalization of physicality via robotics

As an important robotics technology factor, the fact that systemization technology, which represented RT middleware, was created first deserves attention here, i.e. that system integration itself is the underlying technology in robotics. Environmental intelligence technology, created next, was also not of the robotics engineering philosophy up to that point in that it tests whether, it can provide support for the people in the environment and allow robots to operate more easily by intellectualizing an environment and/or structuralizing it.

Of course, though sensors and actuators are also important technological factors of robotics, as an industrial product not limited to robotics they are progressing with a great number of developments and reforms. Though computers particularly are important technological components of robots, they have the role of system architectural components, and it is possible to consider comprehension of system integration technologies such as OS/real-time technology, RT middleware and recognition technologies as recent characteristics.

Some good examples of robotics have been presented below, but we will only provide a summary. For more detail, please read the 2014 'White Paper on Robotization of

Industry, Business and Our Life' (in Japanese).

1. Robot Suit HAL: A power suit targeted towards use in personal care support and rehabilitation. It recently acquired a CE mark and German industrial work compensation insurance coverage; prospects of field use are increasing.
2. Cleaning Robot RoboHiter: A commercialized/business model of the service robot was constructed, resulting in one of the few examples of actual implementation in the office building cleaning business. It is referred to as the best practice among service robot business models.
3. Therapeutic Robot Paro: Aiming for practical use in medical care as the forerunner in therapeutic robots. It is seeing results in Denmark and America.
4. Disaster Response Robot Quince: Developed as a rescue robot, it is a forerunner in the field of disaster response robotics due to its large success at the First Fukushima Power Plant.
5. Robotization of the Entire Hospital: In order to address areas such as operational analysis of hospitals, consulting and system solutions, the idea here is to enable a comprehensive approach to the introduction of robots and infrastructure, rather than individual robots, and this is attracting attention as a potential new business model for robot businesses.
6. Google Car, the Robotic Car: A car capable of autonomous travel co-developed by Google and Stanford University. It is targeted towards unmanned delivery. The use of this kind of autonomous car is starting to be recognized in America, and the formation of a new industry is expected.

All of the above are robots which were developed from new concepts and are already being used practically, are close to practical use, or are anticipated as things which will blaze trails into new fields in robotics.

1.2. Challenges and Proposals for the Years to Come

For the definition of robotics, we proposed something that incorporates societal diversity, not just from the viewpoint of making robots, but from the viewpoint of using robots. The effect this definition produces is not yet determined at the present time, but it is believed that results will be exhibited through the various robotics policies, research development activities and industrial activities that systematically progress along the lines of this definition. That is to say, the task ahead is to foster the communication of people with the interest and intent of developing our society by being involved in robotics, and to co-create the new robotics applications that arise from that. Furthermore, when putting this into practice, we believe that this white paper will be useful as a hint when considering the implementation of industrial activity, social activity, etc. from the technical things concerning robotics.

2. SIGNIFICANCE, NECESSITY & SURROUNDING ENVIRONMENT OF ROBOT APPLICATIONS

2.1. Summary

We have summarized the definition, necessity and surrounding environment of robotics application from global outlook, industry, exhibitions and events, the jurisdictions relating to robotics, regional activities, academic societies and conferences, standards and standardization, and other various perspectives. Robots have developed focusing on improving productivity in manufacturing (e.g. factories,) product quality stabilization, and operations in places that humans cannot easily approach. In recent years, a market of over 10 Billion JPY has been established for the commercial use of robots such as cleaner robots, and their application has spread to medical care, welfare, agriculture, and others. There are particularly high expectations for application in disaster response, welfare and nursing, and the role that robotics technology realizes is not just the creation of new markets; it is also very significant as a contributor to the world's environmental conservation. The approach of having robots that cooperate in a country or area has become normal. Efforts to standardize robots have caught on in light of the growth in the years to come. Middleware specifications have been adopted at international standards by OMG, and robots used for assistance in daily life have acquired ISO certification. Even at events, displays of robots with hypothesized scenes of usage are increasing. The application of robotics is spreading, and the adoption of robotics in electrical appliances, cars, medical equipment, etc. can be recognized widely. It is a momentum which looks like it will become a new industry. While these are truly put in order a robot development environment, they reveal a movement to newly introduce robots to the market. Markets for new service robots targeted towards areas such as high-quality product creation, medical care, welfare, and disasters continue to be made. On the other hand, while Japan is still the best in the world in industrial robots, other countries are catching up. In regards to practical use, many topics come from America. There are projects acting as national initiatives in America, as well those established in Europe such as Horizon2020, and our country needs strong policies that hold prospects as well.

While strong technological prowess and product reliability in industrial robots is improved, application to teaching -free and new fields and production systems via robots are anticipated.

In order to build a dynamic society in which service robots support people in their daily lives, it is important that we build models which seamlessly integrate with networking technology. If we are able to create many applications for them and quickly and safely provide services which respond to the users' needs, the efficacy would be unfathomable. Surely, we should speed up the completion of such a platform.

Furthermore, since education is the cultivation of personnel, it would also support society and industry in every field. Education and education systems with robots as the subject do not just improve the ability to solve challenges; they also incorporate the technical traditions using the interaction of different fields and the spread of robotics technology into society and senior personnel, which is vital.

1) Implementation Potential

In 2010, the Ministry of Economy, Trade and Industry and NEDO estimated the future market (national production) in relation to 2035 in order to visualize the growth of the robotics industry. The results were estimated at 1.6 trillion JPY for 2015, 2.9 trillion JPY for 2020, 5.3 trillion JPY for 2025, and 9.7 trillion JPY for 2035.

In July 2013, the follow-up for the market prediction of 2010 in the "Robotics Industry Market Trend Survey" was implemented as the footing for market scale. The situation is that the Chinese market is rapidly expanding, and Japan, Germany and Korea are working to acquire the market.

2) Definition of & Need for Industrial Robots

In our country, it has been over 30 years since industrial robots have started to become widespread. In that time, industrial robots have been widely used in many manufacturing situations. Industrial robots have had a large contribution to the world's manufacturing, such as freeing up operators from dangerous, dirty and difficult operations (3D), providing products of sound product quality, and making up for a lack of skilled workers. It has been predicted that, in the years to come, there will be an even greater lack of workers because of an aging population and decreasing number of skilled workers. As a result, the expectations for industrial robots are becoming even bigger. The implementation of industrial robots in new fields (i.e. the research, development and manufacturing fields of food, medicine and cosmetics) is also anticipated. Specifically with robots which process reagents and specimens before analysis in the medicinal field, it is possible to acquire highly accurate data with few variations in comparison to when a skilled examiner does it.

Examiners could also be removed from dangerous work environments, such as handling bacterial viruses.

On the other hand, teaching methods remain a challenge for industrial robots. With instruction using a teaching pendant, on top of training required to some extent in before operating a multi-joint robot as intended, in the case of recent robot systems which cause arms with many joints and multiple arms to cooperate, operations require a lot of time. The thing that will be increasingly difficult for the predicted robot systems is the large challenge of simplifying teaching. Within teaching, there is motion trajectory teaching, air-cut teaching, skill teaching, teaching using vision sensor (which incorporates image processing technology), and others, and every one of them requires specialization. In the years to come, achieving no teaching will be required as the ultimate challenge. Because of this, robot intelligence is essential. We need the integration of a variety of research results and the cooperation of research institutes.

3) The Definition of & Need for Robots in Society

A) The Need for Robotic Services in an Severely Aged Society

In order to achieve support in the livelihoods and social inclusion of the elderly and disabled members of our country as we enter into an aging society, the anticipation for robots is increasing regarding services that use them for information provision and support, livelihood support in the house, community formation support, and burden reduction for nurses with regard to bodily function assistance and commercial facilities. We will be able to make the elderly and impaired feel as though they are talking with their children and grandchildren. By experimenting, it is becoming clear that the future functions will promote social inclusion and, through the development of service robots, we will be able to maintain health for a long time, live in a self-sustaining way, work as long as we can with purpose, and participate in society. As a result, it is expected to become the driving force for the creation of new industries and global development for severely elderly society.

B) Robot Service Platform

In order to understand the differences between environment (space), robots, and user, and manage many robots and provide services, we need the architecture of robot service systems. And in order to diffuse those services, there is also the challenge of cost performance. Even if we are able to develop a robot service system, if the value of the service is not high enough to counterbalance the cost, it will not diffuse. If we are able to provide multiple services in one robot service system, projects for the provision of new services will begin to take shape, and we can also expect the projects up until now in which the cost was not counterbalanced to change into projects which counterbalance the cost as a total. For that purpose, the challenge is making a platform which will make it easy for developers which are deeply involved in IT operations to enter into the service robot field.

4) Definition of & Need for Robots in Education

C) Need for Robot Education

Japan is currently rapidly proceeding towards an aging population, and the sophisticated science and technology personnel and manufacturing personnel who have supported Japan's international competitiveness are rapidly declining. In fact, according to the Science and Technology white paper, the current situation is that Japanese people's interest and level of understanding towards science and technology is becoming significantly lower. Despite these circumstances, robotics teaching material application and robotics engineering classroom exhibits have gained attention as a means of training manufacturing personnel and countering fear of science. In different places across the country, robot contest activities are taking place, robotics hobby specialist magazines are being published, and the popularity of robotics is high in the general public.

Robotics technology is the crown of cross-sectional and comprehensive technologies such as motor controls, sensor technology, and machine components, from computer science. As such, through the method of PBL (Problem-Based Learning) and similar which fosters problem detection abilities and the ability to solve problems on one's own, it is suited for composition logic education that leads to the ability to integrate multiple component technologies and optimize the whole of integrated systems. For that purpose, we can achieve success by using science education which targets elementary and junior high school students, widely applicable education materials and methods, and science education in which education targets those in elementary and junior high school all the way to business engineers.

D) Challenges of Robot Education

In regards to the challenge of robot education, the following three trends will become important for robot education in the years to come. The first is trialing personnel training by applying the communities of different fields. For example, robot education activities targeted towards young adults are executed by a local community. It gets the local businesses, broadcasting office, etc. involved and is successful in ranking them in the exchange activities of the entire area.

The second point is the social implementation perspective of leading in robot education. The social implementation of technology viewpoint has been identified in the various documents relating to the 4^{th} Science and Technology Basic Plan.

The third and final point is the application of senior personnel. In the Ministry of Education, Culture, Sports, Science and Technology's 2006 Science and Technology white paper, it already points out that, in the future, Japan's aging population will lead to a lack of engineers and skilled personnel. It demands the securement of human resources that can be used practically, regardless of their age, and the maintenance of environments we can work in. This is an extremely serious problem in personnel training within both businesses and school education. With the current condition of Japan, the practical use of senior personnel is the prominent solution to this problem. We need to establish channels to pass on the man-power, knowledge and experience that senior personnel have onto the next generation of engineers. With robot education, because engineers who are well-versed in the many aspects of technology are competent, the active application of senior personnel who have a lot of experience would be effective.

2.2. Challenges and Proposals for the Years to Come

In this chapter, we summarize the environments surrounding robotics from many perspectives and talk about the needs and significance of industrial robots, robots which contribute to society, and robots in education. In order to achieve medical treatments which allow the elderly and impaired to live with ease, a society with a welfare program in place, a society which keeps disasters and other damages at a minimum, and a society which can pursue frontiers such as space and the deep sea, our expectation is that robotics will be the core in such societies, and that robots provided with high reliability and a low price will be linked with sensors and smartphones, and the spread of robot services will commence.

For skill acquisition and teaching technologies for handing down the skills of adept workers with industrial robots, along with intelligent robots that can make a great variety of products, we also need robotics technology that possesses the safety and cooperability to be able to share and work enjoyably with people. On the other hand, with service robots, we need to use interface technology and robot service platforms which will be naturally accepted into society and achieve service development which has been systemized with logistics and IT.

Robot education has the feature of increasing every generation's inquisitiveness and creative power. We therefore need intuitive integration technology which promotes education, experience and social participation in the daily lives, culture, interests, etc. of every age group. Breakthroughs in challenging task settings will also speed up robot development and implementation, which will bring about new services.

We need to consider all the factors of policy, structure and system for driving these things forward.

3. PRESENT CONDITON & CHALLENGES FOR INDUSTRIAL ROBOTS

3.1. Summary

In terms of the present situation and problems for industrial robots, we started from summarizing the changes of Japan's manufacturing industry since a period of high economic growth as a background of robotics industry, and analyzed the problems of Japan's manufacturing industry, production-goods industry and robotics industry.

The rise of industrial robots had been triggered by the technological progress meeting to the requirement of the manufacturing industry. Due to the oil shock of the 1970s, Japan's manufacturing industry was forced to change policy from investment for production capacity to improving productivity. The manufacturing industry required automation systems. At the same time, microprocessors and high power servomotors were starting to be able to withstand industrial use thanks to advances in electric and electronic technologies. This is the background behind the emergence of industrial robots. The initial growth was supported by the enterprising disposition of Japan's superior industrial engineers and rapidly expanded. On one hand, the basic robot technologies, AC servos with absolute encoders, high performance controller, and highly reliable mechanical components such as reducers were established in the 1980s, becoming technically stable production equipment fixed in Japan's manufacturing industry. Their use in welding within the car industry lead to the initial growth of the robotics industry and was the most important use up until now. With the collapse of the economic bubble at the start of the 1990s, the robotics market, which was showing a tendency towards expansion, came to a standstill. The evaluation points for the advantages of investing in the manufacturing industry became strict, and the market conditions for industrial robots became grave. However, looking back, this was also an important time period because the robotics industry was able to mature from the anticipated preceding trend of the initial growth period to utility value evaluation. The active use of robotics which expanded in that period was flat panel display, semiconductors and other clean manufacturing-process electrical devices.

It was linked to the IT bubble and, and in the year 2000, there was intensive business investment in the clean manufacturing process. Its downstream information equipment and the robotics industry also saw a rapid increase in demand, but it collapsed in a single year and 2001 saw a rapid decrease in demand. It is the robotics industry's second crisis, since the collapse of the economic bubble at start of the 1990s. However, the robotics industry after that had circumstances which could be called a regrowth, and in 2005, a record number of shipments of manipulating robots was reached, at over 81,000. This regrowth became the background for a shift towards the global hub of the newly started Asian Newly Industrialized Economies, with China as the pioneering figure. On the other hand, because of the fear of making Japan's domestic manufacturing de-industrialization, the motivation to challenge robotic application for cell production in response to various-mix various-volume production is rising up even more at the same time in the domestic manufacturing industry.

As is written above, the history of industrial robots has exceeded 30 years, but the value which society expects will continue to change because of the economic and technical background. That is, seeking good robots in the initial growth period of the 1980s, seeking effective applications in the investment strict evaluation period of the 1990s, and seeking reasonable solutions in the regrowth period of the 2000s. In this way, the expectation for the industrial robots have been changing from mere manipulation machines to production equipment which could organize effective production systems. Recently, because of this change, the role of system integrators for production systems in the application of robots has become very important in the robotics industry. Thus far the many experienced system integrators have been a supporting factor of the robotics industry in Japan. The engineering skill of robot system integration is important for expansion in both domestic and foreign markets rather than for the performance of the robots, regardless of their differing situations. The domestic market has been moving towards the challenge of more complex applications, and has been aiming to achieve the highest productivity levels in the world. Foreign markets on the other hand have been moving towards the establishment of new automation regarding Newly Industrializing Economies.

The Lehman Shock, which occurred from the second half of 2008 to 2009, became the largest crisis for the third time, but thanks to a quick recovery, in 2011 a new record for the number of manipulating robot shipments was achieved at over 98,000. However, because this was due to the quick recovery of foreign demand, the robotics industry became an industry extremely reliant on foreign demand since the Lehman Shock. These are conditions which have spread to all of Japan’s production equipment industry, and rather than being a distinct robotics industry and production equipment industry, it is caused by a very serious situation throughout the entire Japanese manufacturing industry.

3.2. Challenges and Proposals for the Years to Come

The number of 2012 shipments for industrial robots was 95,551 at 30.31 billion JPY. Of those shipments, the number of direct exports was 66,871 at 17.92 billion JPY, with an export ratio of 70% in the number of robots and 60% in the amount of money. The current industrial robots are at a record-high level in terms of the number of robots. Heavy international competition seems to be on the horizon in the robotics industry, considering the sudden and large scale globalization of the market. Although the expansion of the Asia-centered market is a great blessing, Japan's robotics industry as a leading supplier and user is facing a turning point..

The degeneracy of domestic demand of industrial robots (representative of automated machines) reflects a slump in domestic manufacturing. Therefore the promotion measures of the robotics industry will also lead to the activation of the manufacturing industry of Japan.. Firstly, in regards to both domestic economic vitality and job security, the rejuvenation of the domestic manufacturing industry is advisable. Even in comparison to other newly industrialized countries, Japan's potential manufacturing level is limited and has no chance of winning in those. Japan needs to continue pursuing world-level cutting edge manufacturing. For that purpose, Japan needs to be resolute and make manufacturing robots a reality, something that was too difficult to achieve until now, and use the robots in the manufacturing domain, something also unable to do until now.

Japan's robotics industry has fostered advanced technologies and a strong framework for the domestic market.

Next is the maintenance of the technology and framework of the robotics industry in order to be able to connect to the global market. Japan's robotics industry has been supported by many system integrators, not just by robotics manufacturers. The globalization of the market has strengthened exports for robotics manufacturers and brought about the self-reconstruction of the business model for the experienced domestic system integrators. We need to view this as a challenge for Japan's entire production equipment industry, and not simply as a problem for the robotics industry.

Furthermore, we also need to cultivate discussions on where Japan's robotics industry seeks its international technological competitiveness. Industrial robots, which are machinery products, also have a level they can attain by learning by example. However, it is not in our best interest to be drawn into the price wars which come with that level. It is not a competition as to whether the combined technology is good or bad. First, we must focus on cultivating the essential component technologies, such as mechanical technology and material technology. Then, we must focus on providing excellent added value as a manufacturing system.

Lastly, in order to overcome the brutal international competition, even if the standard is to leave it to the free-for-all of friendly competition between each industry, we need to provide international competition through common challenges and collaborative frameworks. We need to construct a framework which utilizes industry organizations, academic organizations and cross-sectoral public institutions, and responds to collaboration between businesses, between universities and businesses, between government, universities and businesses, etc.

4. ABOUT LIFESTYLE & SERVICE FIELD ROBOTIZATION INDUSTRIES

4.1. Summary

The field which does not target industrial robots and field robots is called the lifestyle and service field. It deals with products and services closely linked to the regular lives of normal people. This chapter focuses on the businesses which implement ‘robotization’ within the businesses which provide those products and services. Robotization indicates the embedding of robotics technology into systems which only respond to the necessary goals. It is an opinion which is taken very seriously in creating “robot business” within this field. Placing emphasis on this opinion does not just refer to making robotics industries or industries which make robots; it also refers to the expansion and grasping of industries born from the products and services sought by the market, and the robotization of the commercialization process of those products and services.

Robotization can be applied to all products and services and their commercialization process, but doing so does not mean it will increase their business. Therefore, as a guide for succeeding in robotized business, this chapter discusses:

(1) whether businesses which were created using robotization will continue to prosper within the business models and target fields used up until now;

(2) what kind of level the research and technology which supports them is at;

(3) the important legal systems, standards and national assistance methods when creating the new industries; and

(4) the attitudes of the major nations.

1) The Main Business Categories and Examples

When examining the founding of robotized businesses, the examples are categorized from two important perspectives. Those perspectives are what kind of business model it will use, and who the main target audience is and the benefits it provides to them. In regards to the former, it is categorized into the following four types:

1. Product development and sales businesses which have robotized pre-existing products. Hardware product development, production and sales businesses which have non-conventional customer value by embedding robotics technology into cars, electrical appliances and nursing and welfare instruments which already form the market.
2. Service innovation businesses which use the robotization of service processes. Businesses which create new service businesses and engineer the service processes by applying robotics technology, dramatically increasing productivity, and provide new customer value. The products provided to the customer are services, not hardware.
3. Total solution businesses which apply robotics technology. Businesses which provide a combination of the perfect solution for individual customer tasks and a product which maximizes customer value with the application of robotics technology. The provided product is the whole-product configuration of hardware, software, contents and service.
4. Service robot development and sales businesses. Businesses which develop, manufacture and sell

hardware products for pre-existing products in non-conventional technology which once had difficult functions and that have no category.

The categorization from the viewpoint of the latter is application. The nine applications or target markets below are proposed:

1. Daily life
2. Entertainment
3. Welfare
4. Education
5. Medical care
6. Facilities and offices (cleaning, security, meetings)
7. Hotels and dining
8. Transport (mobility)
9. Urban space (advertising, public, circulation, distribution)

From among the businesses which are a mix of both of the categorizations, people who were directly involved in the starting and promotion of businesses within these fields have written us examples which serve as a reference for creating a business.

1. As an example of a robotized business for a pre-existing product, cars with functions and automated operation technology (which is yet to come) equipped in order to avoid hazards (cars which have recently been having their introduction planned at a staggering rate).
2. As an example of the robotization of service processes, advanced security service businesses and private night-school services.
3. As an example of total solution businesses which

apply robotics technology, entire hospital robotization businesses.

4. As an example of service robot development and sales businesses, the therapeutic seal-type robot ‘Paro’ and the HAL robotic suit, etc.

These specific examples present the most recent status.

2) Research and Technology Trends

In regards to supporting robotized industries and the research and technology that holds the key to the creation of innovation that the support encompasses, we have divided them into basic research and technology field and the research and technology being focused on. We have presented themes below which are highly important. Each of the themes presented has been written by leading experts in research on those themes.

The four themes presented in basic research and technology field are locomotion, manipulation, communication, and transmission and networking. The eight themes presented in research and the technologies being focused on are safe engineering, spacing intelligence, service engineering, humanoids, BMI, cognitive development systems, life design, and elderly people.

Because robotization is the integration of the research and technology of various components, the relevant research and technical fields are extremely extensive. However, due to space limitations, only the themes which have been significantly narrowed down have been presented here. As has been mentioned throughout this chapter, if it is important to robotize and not just make robots when considering commercializing or implementing robots into society, then how to proceed with the design of the intended space, services, life and society systems for robotization will also become extremely important in the future. Within the research and technology being focused on, several themes have been presented from that perspective.

3) Industrialization Promotion Policies and Related Laws

Robotization could cause a shift in the relationships of performance and cost, personalization and mass production trade-offs and be the approach which achieves the changes we were not previously able to attain. Therefore, the robotization of the lifestyle and service fields which this chapter focuses on could be the steps to change to an entirely new social system and lifestyle, not just as a conventional product which satisfies the current society and lifestyle or a service's niche product. For example, even for the various challenges caused by elderly society which have never been faced in the past, we can expect it will result in finding new solutions. However, the legal system which regulates the existing society and lifestyle and the customs which are being naturally performed within it will be affected based on the circumstances, so much that it will affect the way we think. We need to identify the problems which will be hypothesized, suggest what the new society and lifestyle will be like and attempt social experiments with the participation of many people while continuing forwards. While keeping the process with these changes in mind, many countries have been developing promotion policies up until now, and, especially recently, policies which spread over government agencies are being actively promoted. For example, the 'Robotic Nursing Equipment Development and Implementation Promotion Project,' one of those policies, is a project which supports the high-priority field of robotic nursing equipment within nursing application robotics technology. This project is being planned by the Ministry of Economy, Trade and Industry and the Ministry of Health, Labour and Welfare together. It aims for the creation of a new market for robotic nursing equipment while achieving the promotion of independence for people who require nursing care and reducing the burdens of nursing practitioners.

A wide range of the major laws and systems which have a large effect on the promotion of robotization are also being raised. E.g. the Road Traffic Act and the Road Trucking Vehicle Act for the new mobility which suggests the automated driving and road operation of cars, the Civil Aeronautics Act for unmanned air vehicles, as well as the Radio Act, Illegal Access Law and Private Information Protection Law, the Production Liability Act, the Pharmaceutical Affairs Act, the nursing-care insurance system, Foreign Exchange and Foreign Trade Law export control, etc. Some of these legislations get industrialization started by making the regulations when necessary, while some ease the regulations and form the market. In regards to the latter, we need to make use of the efforts of specific zones, conduct social demonstrative experiments and measure the results and optimum regulation. The efforts of Tsukuba Mobility Robotics Experiment Zone were presented as a specific zone which relates to typical robotics. Efforts for the standardization of service robots have also been intensifying and, in regards to personal safety in particular, Japan is leading the way in designing standards. Japan is conducting research on institutional design, such as safety testing methods, safety standards and safety authentication, while also introducing the ‘Life Support Robot Safety Testing Center’ which was established to fulfill the central role of creating standards based on the tests and test data, etc. From the perspective of standardization as well, they are also introducing ROS, which is becoming popular as an RT middleware and robotics operating system. It is a software platform which combines robot function component software modules and constructs robotic systems.

4) Status of Major Foreign Countries

For a long time, Japan was predominant in efforts which concentrated on research, but it has gotten to the stage where Japan is not making any progress in industrialization and implementation into society. Several countries have intensified their activities, and Japan can no longer sit around doing nothing. The countries which are actively planning on the implementation of robots for the elderly and people who require nursing care are European countries such as Denmark, as well as Australia. The fact that the industrialization of the robotics industry is getting generous support in Korea and that the growth of other industries in China will similarly become faster, all because of major investment due to national policy, has also been noted. We should be paying attention to America in particular. Both in the past and presently, America has been the starting point for the creation of new industries. But even in robotics, America has been coming up with environmental arrangements which develop innovations through robotics technology (e.g. the unmanned car DARPA Grand Challenge, establishing laws which recognize the operation of unmanned cars on roads in Nevada, the DARPA Robotics Challenge in which robots had to clear disaster site response tasks, etc.). This is a threat to our country.

4.2. Challenges and Proposals for the Years to Come

Hereafter, the form society will take will be a mature society and an elderly society. What is common to both is different for the needs and desires for each individual person. The demands which satisfy those individual people will increase.

Within mature society, an individual chooses and acts in order to satisfy themselves. That satisfaction is fulfilled when we realize the form we ought to have. The industry will therefore move in the direction of drawing on the competitively superior products and services which help it to survive and achieve the satisfaction of individuals as well as those self-realizing desires, and clarifying and achieving those desires while co-creating with each individual.

In addition, it will also seek more human-like lifestyle and work in mature society. The things that humans should do and the things that are best done by humans will be handled by humans, and we will seek mechanical systems which substitute for humans and include them in their system. Even in those circumstances, how much is best left up to the mechanical systems for each individual will be the problem. Optimizing for individuals like the ones above will be possible by understanding the characteristics and circumstances of each individual, discussing and learning what they want, and providing the service which is adequate for those things. However, this can only be achieved from a highly complex level of unconventional methods from the perspective of cost and output by combining robotics technologies.

On the other hand, in Japan, which has the highest population aging rate in the world, the urgent theme is solving the problems which are caused by an aging population. If we are able to solve those problems, we will be able to provide a solution to this challenge which would help other countries face this same problem in the future. However, many factors are interrelated for this problem and it is not a problem that can be easily solved. As we become older, not only do our bodily functions inevitably decline, but our opportunities to participate in society and our opportunities to be active in daily life also decrease. These have a negative effect on each other and, from the perspectives of health and finance as well, it falls into a vicious cycle. Furthermore, these circumstances are extremely varied for each individual. We need to understand the physical and mental state of each elderly person and their status of activity, have discussions with them and draw upon their interests and goals, identify the bodily functions which are required to achieve those things, and encourage them to participate in activities. In regards to the implementation of robotics technology, we will be able to detect and predict the support, expansion and conditions required for supporting bodily functions and achieve high financial optimization for a large amount of individuals, something which we were not able to achieve before.

The first challenge for the years to come will be upgrading the robotics technology which satisfies the individual and is optimized to them, and creating a business model which establishes that. In particular, within the industrialization of robots, discussions for business models have been put off up until now. When talking about the robotics industry, it is important to take the thought of an industry which makes robots, re-read it as the 'robotization industry,' and replace that thought with an industry which provides customer value through robotics technology. From the perspective of a business model, it is believed that it will provide a total solution in order to satisfy each individual customer.

The second challenge for the years to come will be the need to solve the problem of how to optimize for the individual and how to optimize for all of society at the same time. We will need to control the nature of the relationship for each human and optimize from the perspective of cost and benefits on a level which cannot be achieved using conditional methods as a whole community and whole society. In terms of how we will integrate it, we will need to discuss community design and social system design methods. In other words, in order to respond to the problem of optimizing as a whole society, as well as developing and applying robotics technology (e.g. technology and big data which senses the environmental and social circumstances, controls movement, etc.) for controlling optimization for the individual as a mass, the most important thing is establishing social system design method debates and then establishing methods which socially prove the hypotheses derived from those debates. It is essential that we have these debates and have architectural development which can produce a social system and business system.

5. CURRENT SITUATION & CHALLENGES FOR FIELD ROBOTICS

5.1. Summary

In a narrow sense of the word, field robots are defined as robots which work outdoors. In a wider sense of the word, they are defined as remotely operated machines which operate either indoors or outdoors. Because cars are dealt with by the car industry, the things within the new perspective area of field robotics written in this white paper are things which are included in the category of field robots.

Field robotics has had a significantly long history, even when compared to industrial robots. But in spite of the high expectations, the full-scale market investment will only begin in the years to come. When considering the future of field robotics, you should not just picture a market solely of robots. It is essential that you picture a market which considers new answers for making a society which can solve the various challenges of the arrival of companies needed for robotics, guaranteeing the comfort and safety which we have presently, a decreasing birthrate and aging population, environmental preservation, etc. as part of the bigger picture of field robotics and robotic systems.

Using the opinions mentioned above, this chapter focuses on financial improvement, avoiding hazards and creating a new society in regards to field robotics and considers how many fields could develop intellectually from it.

1) The Current Development Status and the Market

A) The Field of Construction and Public Works

In regards to robots which are used in the construction and public works fields, in the initial development stages before 1990, ensuring the safety of the operators by improving the working environment was the focus. However, due to the collapse of the economic bubble, that goal changed to pursuing economic efficiency. As a result, many work-specific robots were developed within the industries and construction robot research development projects at universities such as concrete flooring robots, but these were not being widely implemented to substitute for people. Automatic construction systems which make building constructions ready for factories were implemented, but there are restrictions in terms of cost so they are hardly used now. However, in recent years, automated systems similar to building deconstruction work are being used. In the years to come, robotic systems which use all of the past knowledge will be implemented with the progression of the increasingly aging population.

B) Social Infrastructure Maintenance Robots

Social infrastructure maintenance robots have been developed primarily for structural inspection automation requirements (e.g. bridges, tunnels, public facilities, etc.). However, the market still has to grow more before it can be called a proper market. The main reason for this is that concept of robotization has not been considered at all for the target structures, the inspection methods rely heavily on people and other robotics implementation failures have been largely ineffective. Infrastructure maintenance has progressed robotization while promoting coexistence with people. However, in regards to social infrastructure which plans using national land strengthening concepts, robotization will develop greatly by taking constructions which consider robotization from the construction phase.

C) The Field of Plant Maintenance

Chemical plants, which are typically oil plants, are becoming older and maintenance is essential to extend their lifespan. Yet, because of this field's poor accessibility, which is worse than that of social infrastructure maintenance, and the difficulty of inspection, robotization has not had much progress. However, with the decreasing number of experienced maintenance personnel and the increase of both the development and operation methods of robots which have economic efficiency, ease of use and high inspection efficiency, implementation of robots which focus on maintenance and repair will gradually progress.

D) The Field of Agriculture

The aging of agriculture workers is a serious problem. As a result, the development of individual robots such as tomato or strawberry gathering robots and soil disinfection robots for reducing the workload of agricultural jobs is proceeding. In overseas large-scale farms, robotization in the form of agricultural equipment is proceeding steadily. However, in Japan, because of the complexity of narrow farmland and hilly and mountainous terrain, the decrease in operation rate and increase in costs are becoming hindrances for implementing robots. Therefore, the key to implementing agricultural robots is how we can solve these hindrances. On the other hand, there are already limits with an aging population. Robotizing by upgrading the current agricultural equipment as well as implementing robots with the collaboration of a new agricultural system which would be observed by plant factories are inevitable circumstances. By perceiving agricultural field robots, including the timber industry, as part of a larger food security and national land conservation system and not just as the pursuit of economic efficiency, the importance of implementing robots will become larger.

E) Disaster Response Robots

After the large earthquake in Eastern Japan, interest in disaster response increased dramatically and interest in disaster response robots also increased. However, just like with the First Fukushima Nuclear Power Station response robots, in Japan, there is no regular market for disaster response robots and there is a large difference in market formation power compared to various Western countries which can be involved in military robotics. Yet we cannot disregard the human and economic costs. In Japan, which can be called an archipelago of disasters, if we can nurture a political market with the viewpoint of national and social preservation from the perspective of saving lives and ensuring the safety of the people involved in it, the implementation and application of disaster robots will progress.

F) The Field of Nuclear Power

In order to handle radioactive materials and in order for operations to persist under high radiation environments, there are many needs to use robotics technology and work using remote operation to help prevent and reduce the exposure of workers. Within the various plants which began nuclear plants and nuclear fuel processing plants as well, the development and implantation of remotely operated machinery has been done in response to each of those needs.

The Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Plant accident occurred because of the large earthquake and tsunami that happened on March 11, 2011. Within the medium to long-term measures taken for responding to this accident and decommissioning the nuclear reactor, the need for extremely diverse and important robots and remotely operated machinery arose. Directly after the accident as well, the amount of radiation in the area around the nuclear reactor building was extremely high because of the contaminated materials which had been emitted. The use of machinery which could be operated remotely such as robots was needed in various situations. In response to these diverse needs, many robotics technologies have been introduced up until now. In the years to come, we need to further develop and introduce robotics technology which focuses on decommissioning reactors.

G) Other Field Robots

Though they seem difficult to make into a large market, even in the near future:

1. space application;
2. deep-sea application; and
3. military application

are being presented as fields which use highly technically complex and environmentally characteristic robots which realize dreams. However, the goal of using military robots is a special exception. Within the basic functions, even if it has common elements, it should perhaps be classified under a different category to other field robots.

2) Technology

There are many field robots which can both move and work and need all of the general robotics elemental technology. All of the considerations listed below are highly important technologies which are needed for field robots to work under outdoor environments.

- Adaption to natural environments: the ability to adapt to uncertainties, minute-by-minute current events and environmental factors a person cannot control in natural environments (i.e. typical countermeasures for environmental variations e.g. day and night, rainy weather, wind and rain, extreme temperatures, etc.)
- Uneven terrain response: the main major difference to cars which travel on the road is the ability to adapt to modeled difficult and uneven terrain
- Support environment installation: if we prepare a robot infrastructure for robot adaption areas, its application will promote practical use

A) The Field of Construction and Public Works

What made existing man-operated equipment unmanned and promoted field robots was the use of high precision GPSs. They have a bright future in large-scale mining etc. and GPS radio waves are rarely masked. By allowing for a certain degree of running error with road-width assurance and managing the safety of people within the controlled mining working environment, it is able to provide highly reliable navigation.

Unmanned construction is an excellent remotely operated construction robot system which is being used in

Japan. This system is a combination of remote operation and automated operation. It accomplishes stone removal work, etc., from a safe place several kilometers away using unmanned construction machinery, a television picture and GPS to protect workers from the unanticipated pyroclastic flows which come with Mount Unzen-Fugen's eruptions. It has also played a part in Mount Usu eruption countermeasures, countermeasures for landslides caused by heavy rain, the Fukushima Daiichi Nuclear Power Plant accident emergency response and debris disposal, etc.

Construction work requires operations under various work environments. As a result, by handling the entire construction work as a system, the results would be very large, even more so than robots for individual operations. Computerized construction system technology which uses ICT is being developed for that purpose (the Ministry of Land, Infrastructure, Transport and Tourism).

B) Social Infrastructure Maintenance Robots

Accessing difficult places is a characteristic of social infrastructure maintenance robots. There are many examples of challenges caused by adsorption, such as concrete wall surface movement, magnetic steel structure movement, electrical line movement, vertical ladder movement, running drainpipes, etc. However, because the access methods are unique they are not suited for general-purpose application. We need to develop an access system with different ideas. It is also important that we maintain motivation and communication. Many processes have been proposed for the handling of wires in the case of a fixed line, which is usually the case.

C) The Field of Plant Maintenance

One technology which is characteristic of plant maintenance is accessing plumbing and building structures. There are many examples of pipe bends and pass valves being developed in response to special machinery, magnetic force, etc., as well as some examples of using things like tank wall surface inspection equipment. Creative proposals have also been shown for the treatment methods of cables which interfere with operation. However, there are both advantages and disadvantages to this. There are also no general solutions for closing of pipes when robots malfunction and we have no arrived at a point where practical application is limited.

The thing we need first for plant and infrastructure maintenance is the verification of the integrity of the subject. We therefore need to make a robotics system which uses both an optimized combination of inspection methods and proper signal processing methods and has ultrasound, eddy current, rattle and visual inspection technology that both form robotics technology and perform maintenance.

D) The Field of Agriculture

The robotization of agriculture in Japan needs countermeasures for narrow farming areas and diverse land. In response to this, proposals are being made for wheels which incorporate past agricultural machinery and crawler motion machinery. Implementing high precision GPSs is also becoming popular and harvesting robots are being developed with highly precise motion. However, we will need some new schemes which do not have technical developments for the individual response robots in the years to come.

E) Disaster Response Robots

What we need in disaster response is technology which can move every type of sensor to a scene, perform mapping, etc. and inform people of those things in an easy to understand way. The next thing we need is relief and restoration work capability. There are many cases of disaster response robots being required to work in unpredictable environments. It is important that they have a mechanism which effectively uses human judgment. It is also important that we become familiar with operating robots and robotic functions and train and educate operators who can construct field environments. Uneven terrain travel technology is also technology that is unique to disaster robots. Research developments for making uneven terrain adaptability common and the adaptability of humanoid robots to disaster response environments are currently being performed.

F) The Field of Nuclear Power

In regards to handling radioactive material in hot cells, master and slave manipulators have been used since long ago. On the other hand, there are also many cases of specialized machines which observe, inspect and maintain nuclear power plants (such as under water inspection robots) operating in actual plants. Within the emergency response and reactor decommission measures which are being taken for the Fukushima nuclear accident, a large number of robots, remotely operated machines, etc. are being developed and used for examining, removing rubble, decontaminating, etc. Even robotics technologies which are not what you might call ‘robots’ where used in various operations in decommissioning the reactor.

5.2. The Challenges and Proposals for the Years to Come

We will now discuss proposals which incorporate the definition robotization and the new perspective from three different viewpoints. Each point will be discussed in detail.

1) Field Robotics Which Will Improve Economic Efficiency

Only the market decides the evaluation for improving economic efficiency. We cannot present a specific plan for lowering costs, but when considering that upgrading construction machinery will lead to construction field robots, the solution lies in high quality construction machinery construction robots. That is to say, if we are able to achieve dual-mode construction machinery, we will need to not have construction robot hardware with special specifications. The rate of operation will increase and we will be able to use them as disaster response robots in emergencies. There are challenges for making robots dual-mode, but there is nothing we cannot solve with technology. It can therefore be said that the advancement of robot development and development of dual-mode technology is the shortcut to the widespread use of construction robots. From the perspective of upgrading agriculture machinery as well, this dual-mode technology could develop agriculture and forestry robots.

2) Risk Aversion Field Robots

Assuming that disaster response robots are the representatives for risk aversion robots, we need to make disaster response organizations a national policy to make their use widespread. However, because there is a movement to point out how lacking in experience robotics technology is, for the meantime, we must proceed continuously with plans for widespread use through the development of robotics. In regards to current developments, it is essential that we take action to achieve organizations with a long-term perspective. Even if we only pursue immediate application, as long as there is no feasibility, we have to make use of the effects of learning about the danger of ending with research development when we make something.

Furthermore, in regards to decommissioning the reactor at the Fukushima Daiichi Nuclear Power Plant, the mission is just that—decommissioning the reactor. Even if those robots come under the category of risk avoidance robots, they must have a unique application. However, because it is possible that they will have similarities to disaster response robots, from a long-term perspective, it is essential that we develop technology in cooperation.

3) Socciety Creation Field Robots

Calling it society creation may be an exaggeration, but Japan's declining birthrate and aging population problem is a problem the likes of which have never been seen before. If we are to solve this problem then our only option is to create a new social structure. If we are to keep a vibrant society with the sharp decline of population (specifically workers), then surely our only option is being supported by robotics in some kind of form.

Field robots will have a large role in assisting in solving the challenges of under population and concentration which are predicted to occur in this process, particularly in solving and assisting in the challenge of an under populated society. Regions where population has not accumulated which can be called limited communities are stereotypical of underpopulated areas. The concept of robotizing every village would be a large key in solving this problem and field robots would be the large foundation for that. It is possible that this would lead to a debate with hundreds of schools of thought participating, but in order to solve this problem without getting rid of those villages, it would not be wrong to say that having field robots, including unmanned vehicles, is important. Even if we were to get rid of the villages, considering that the problem of limited community is transitionally inevitable, field robots will become increasingly important. A specific example of a new viewpoint of field robots has been presented in 7.2.5 of the main text so we will not mention it here, but many knowledgeable persons have acknowledged that limited community is a problem that will engulf every urban area. For example, the success of field robots as agriculture systems indicates the large potential for Japan's future.

6. MAKING ROBOTS A PART OF SOCIETY

6.1. Summary

This chapter is not a forecast discussion made from current technology like all of the previous chapters; it paints the vision we should have in the future and identifies the steps for having a back-cast discussion on the technology required for that vision. It reflects on the fact that a combination of the existing RT components will not lead to a solution for social challenges.

1) The Necessity of Service Driven Robot Desgins

For small social challenges, we should consider services for people. It is believed that thinking about the shape of those services and the technology and things that will be required for it could very well lead to a new robot industrialization. We need service driven robot designs.

2) The Vision of Society We Should Have

Globally, the population rate of people over 65 years of age has been increasing with developed countries at the center. In 2050, it is predicted that the world's entire population of people over 65 will reach 16.2%, and 26.2% in developed regions. Even so, the growth of Japan's aging rate is on an entirely different level and Japan will be the first to experience it. An elderly society like nothing the world has ever experienced before is right in front of us, and it seems inevitable.

Even in all of the regions of Japan, the wave of elderly society is pouring down on us. Especially in regions which are already underpopulated, because their youth do not return when they move to cities to attend university and for job opportunities, statistically adding the aging rate to their current population not only increases the number of workers; the decline in birth-rate caused by the decline in youth also furthers the increase in the aging rate.

The one other point we should pay attention to in population changes is ‘population concentration in urban areas’.

One group in the AIST project made the hypothesis below in regards to what we should have in an elderly society.

“By humans of different ages and gender who have various experiences continually having confidence in each other and forming a connection, it will be a society which people can be psychologically secure as individuals.”

However, in order to provide an ideal lifestyle based on the hypothesis above, we may need urban development which expands the things we could have, such as a social security system, while also making a system which can take care of us as much as possible in times of crisis and resides nearby instead of together while making preserving ties between people as a social system a possibility.

3) The Process to Make ‘The Things We Should Have’ a Reality (System Design and Maintenance—Backcast)

We will now deal with the possibility of making the things we need written in the paragraph above a reality and refer to the process. In normal situations, national and local government urban development in 20–30 years’ time would require urban development ground design for elderly society and the back-cast policies that come from it. Solving large social challenges means dealing with extremely complex and large problems. While searching for conventional common solutions is impossible, we need to apply the same constraints of a specific region and search for a characteristic solution.

4) The Process's International Competetiveness (International Standards & Promotion and Safe Technology & Certification Systems)

This presents dealing with a legal system, international standards, projects for the practical use of life support robots and safety inspection centers in regards to the safety of robots as examples of problems when confronting social implementation.

6.2. The Challenges and Proposals for the Years to Come

We believe that, unlike with the existing development steps of stacked robots, revealing the things we will need for the final form, adversely deciding the individual components which will be needed will help with the social implementation of robots (vastly different to the steps taken for designing and developing the existing robots).

If the robotics development up until now does not change from the phase 'technology which aims for social verification by combining individual components' to the phase 'technology which aims for social implementation by removing components it does not need' then, in the true sense of the term, we will not be of any use to society.

Particularly in this chapter, multiple examples which are removed from the individual technologies of 'urban development' are presented at a glance. This is because, due to system engineers (to whom combinations of RT are significant, much like robotics researchers) being involved in urban development, being able to organize complicated problems while robots and RT components (which are part of the puzzle for solving the social problems) become complicated is believed to be the new social implementation process for robots.

Nowadays, with the beginning shift from objects to cost, there are many industries that are beginning to change from industries which manufacture objects to industries which manufacture services which are beginning to appear (IBM, etc.). Even within object manufacturing in particular, the sections which construct service-inclusive service systems are generating a profit in regards to upstream design, as can be seen with ‘iPhone’ and ‘iTunes’. And as for downstream design, by slashing prices at any given point in time, it is needless to say that the profit margin is small in proportion to effort.

It would be inaccurate to say that Japan does not already have an upstream design and service design. Japan has the blended culture of the upstream design of ‘craft’ and the downstream design of ‘work,’ which together form ‘craftwork,’ but we may have forgotten the part of ‘craft’ somewhere along the way.

While doing upstream design, industry construction in which craftsmanship can be utilized may be needed of Japan in the years to come.

Editor's Note

For Forming a 'Smart Society Which Builds Robotics Technology'

Consider the role of robotics technology in Japan

In recent years, the voices which fear the decline of Japan's industrial competitiveness, a country which has relied on focusing on technology and manufacturing, as well as debates on 'the lost 20 years,' are no longer a rarity. With the grim circumstances of the progression of a dwindling birthrate and aging population, the overseas transfer of the manufacturing industry, etc., Japan, a country which uses technology and personnel as resources, needs to create good partnerships with countries all over the world while preserving the growth of the economy. In order to achieve this, Japan needs to maintain its one-step-ahead advanced technology (object manufacturing) in comparison to the emerging nations (which aim to catch up to the developed countries) while having an advantage when competing with developed countries in technology development. It is also essential that Japan maintains and strengthens its industrial competitiveness within the global business environment by providing services with high added value (service manufacturing) to developed and emerging nations, etc. Even in the various types of government white papers and reports, the same argument stands out.

Particularly in the field of 'service robots,' for which expectations of being industrial competitive strength and a provider of national wealth in the future are increasing, there once was a time when everyone welcomed the advancement of technology because of performances, such as welcoming guests, playing music, etc. Presently, robotics technology is a part of the scene of our actual lives as though it has melted seamlessly into our day-to-day lifestyle and our social system, from 'performance equipment which tells a dream' to 'robotics technology' (RT) in close relation to life and society, such as mobile objects which detect obstacles, etc. and perform self-controlled operations and the overall efficient transportation and distribution systems which use them, the optimized health management information for individual people which uses big data and various types of sensors, information terminals which provide an observation function during nursing care, electrical appliances, security systems and the smart homes and cities they have been installed in, etc. The use of robotics technology is starting to spread without us even noticing it as basic component technology which provides robotics technology-like 'solution services' which are a combination of safe, reassuring, comfortable, convenient and pleasant components.

We call this 'service robot solution business industrialization.' Japan's service robots ultimately aim for this, and various policies, such as large-scale research development national projects, are being dealt with every day. On the other hand, regions and areas are not being stimulated and within over-concentrated developments, which only help large cities to prosper, there is believed to be a limit as to how much of the 'lost 20 years' Japan can get back. In order for each of the regions to combine and draw on their own distinct characteristics (human resources, local industries, special products, tourist attractions, etc.) and robotics technology (RT) and information technology (IT), such as networking the artisanal skills the various personnel in the region have and making the citizens' lives safe, reassuring, comfortable, convenient and pleasant like a 'handyman that has been made convenient,' they are beginning to utilize it and harness it towards the region's medical and nursing cares and make use of the world towards other parties in their own way while also utilizing the internet. Efforts are being made to use that data as feedback for remanufacturing etc. and foster a realistic regional economy and social system in a robotics technology-based local area. Furthermore, in recent years, efforts to combine the technologies of the different fields collaborating with the government, industries and universities in combination with the movement to make the primary sector industry a 'six sector industrialization,' create new technologies and services using the interaction and education of human resources, develop new demands and bring the regional innovations and economic development which have distinct characteristics to fruition are also beginning.

In the past, it is true that there was a time when we tried to adopt robotics technology beyond reason, even for the things which humans were able to do more adequately (would you want to listen to classical music through the accurate performance of a robot or through the richly expressive performance of a professional?). However, in the years to come, we believe that we will transition to a stage which we will achieve the widespread use of robotics technology. This will be because of the movement to form a smart society which aims for the suitable incorporation of robotics technology in our surrounding living environment and social system without a sense of discomfort.

Japan can become stronger with robotics technology

'Industrial robots' has supported Japan's high economic growth and high-quality product manufacturing. However, in recent years, the development and use of industrial robots in developing countries has been actively progressing. The industrial robots has traditionally provided 'industrial equipment' and 'industrial systems' as an occupation in order to achieve high-quality manufacturing. However, in combination with actions to for the production and consumption base to move to move to emerging countries such as in Asia, we need to construct industrial systems which are not an extension of existing ones (e.g. be able to deal with the soft bodies which we were difficult to handle up until now, have a significantly higher rate of operation and production efficiency, be able to respond even to seasonal, variable quantity and variable type productions etc. with a portable system that can be flexibly applied to installation sites, be able to safely use operations which co-exist with people, etc.). We need to establish those things, including system engineering, as a more global production and distribution system with high added value and convert the high-quality 'product manufacturing service' which has been Japan's base to a system that provides globally.

Even in regards to robotics fields that participate in the event of a disaster (disaster response robots, special environment robots, field robots, etc.,) although we cannot say that they were the first to participate in the previous nuclear plant accident site because of maintenance and management restrictions, Japan's robots were able to admirably achieve the missions that even the military technology and the Western robots which have a history of using that technology were not able to achieve. Japan currently has infrastructural risk, risk of capital city inland earthquakes, risk of Nankai Trough earthquakes, etc. If we learn from the current density of manufacturing facilities etc. on the Pacific side, should a Pacific Trough earthquake occur and manned operations be ineffective, it is clear that Japan as a whole would need a quick emergency response and restoration and reconstruction operation that uses robots. Furthermore, if we turn our attention to the large-scale CBRNE disasters (disasters including chemical agents, biological agents, radioactive materials and explosive materials) which occur all over the world every year and are caused by natural disasters, accidents and terrorism, etc., it is possible that Japan’s robotics technology, which has a wealth of experience, will be able to participate globally in reducing and preventing disasters in the future. The possibility of contributing to domestic and international manufacturing facilities etc. as a business is also expanding.

Making Japan's robotics technology the provider of the strength of Japan's industrial competitiveness and national wealth

Using portable information/music devices and household gaming systems as an example is self-explanatory. However, even if we were to simply develop 'hardware' as a machine, if we do not organize the software and OSs which have appeal, the usage environment, the infrastructure, etc. (which upgrading would require a strategy for), we cannot expect developments in regards to their widespread use, their implementation and the industry. There are also limits to the technological seeds of proactive robotics technology which have been complacently developed by robotics researchers. If we do not develop robotics technology that is useful in responding to the actual context and needs from the perspective of the user, the market will not be accepted.

We have tried writing and editing the 'White Paper on Robotization of Industry, Business and Our Life' for the purpose of achieving the active application and widespread use (both domestically and internationally) as well as the revitalization and development of the robotics industry by organically linking valuable resources of the various research relating to the robotics technology which has accumulated up until now (such as results, know-how, experience, human networks, etc.), giving continuity and coherence to them while continuing to accumulate it, and appealing to people who are unfamiliar with robotics technology with issue awareness and thoughts of the future which consider robotics scholars, manufacturers, users, system engineers, etc.

There are several challenges for robotics technology and the environment that surrounds its industrialization. We will need some under-the-surface innovations in order to foster the superior robotics technology that has been cultivated up until now which can also be called Japan's knowledge for the next generation of key industries which will achieve industrial competitiveness and national wealth. By presenting the people who read this white paper with the interest and understanding concerning the necessity of Japan's robotics industry, the possibilities, etc., we hope that this 'White Paper on Robotization of Industry, Business and Our Life' will be able to help them contribute to the development of the robotics industry.

Lastly, this 'White Paper on Robotization of Industry, Business and Our Life' has been written and edited through the cooperation of celebrated specialists who actively participate on the front lines in the field of robotics technology. In spite of its broad subject matter, these people have approved the purpose of making the 'White Paper on Robotization of Industry, Business and Our Life'. They have written the essentials that make up the basic structure and 'backbone' of the 'White Paper on Robotization of Industry, Business and Our Life' (2012) and written and edited specific drafts based on those essentials (2013). In those cases, the 'White Paper on Robotization of Industry, Business and Our Life' Editorial Committee (Chairman Tomomasa Sato, specially appointed professor at the University of Tokyo) have been responsible for discussions on problem awareness and the possibilities regarding the robotics technology we should have as the basic ideals that persist throughout every chapter, the balance of every chapter and the message to the readers as they look over the entire structure of the white paper. They have also established a total of 6 WGs in all of the chapters, discussed problem awareness etc. and printed them. It would not be an overstatement to say that this white paper was only possible due to the efforts of those specialists. We would also like to give a word of thanks to the people at Mizuho Information and Research Institute who were responsible for outsourcing the data acquisition, the committee head office and the people in the Industrial Machine Division at the Ministry of Economy, Trade and Industry who gave us advice and support from many different angles for making the 'White Paper on Robotization of Industry, Business and Our Life'.

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