HUMANOID ROBOTS, AND THE CULTURE AND HISTORY OF THE JAPANESE PEOPLE

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1. Introduction

1. 1. *The current situation*

Robotics is, perhaps, the field that has most rapidly developed over the past decade or so. Particularly in the area of industrial robots, robots are being as equipped as standard in manufacturing plants all round the world, and robotics has reached the age of maturity as an industry in its own right. Now the development of industrial robots – highly reliable and capable of mass-producing high precision goods at a low cost – for activities outside of factories is under examination. This includes, for example, in the urban environments where the majority of people live, as well as in homes. Against this backdrop of efforts to expand the robot market, a problem arising in Europe has been posed.

In Europe, and particularly in Western Europe, there are many people who regard the development of technology as something that is built upon the sacrificing of people. Examples of this that could be cited are the digital divide and techno-stress. With the development of technology seen as a malady, the view is that the operation of equipment that elderly people already find difficult to carry out will become excessively so, that prices will be so expensive that technology becomes a monopoly of the affluent, and that the timing of work will hinge upon the whims of machines; and despite the fact that age

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and income-related disparities and moral and ethical issues are being pointed out, nobody knows what sort of effects will be felt if robots are introduced to cities and homes in the future. The First International Symposium on Roboethics, held in 2004, was convened in order to raise these sorts of issues and make an international agreement on them.[1]

The country that hosted the symposium was Italy, and it was held in the city of Sanremo, where the discoverer of dynamite, Alfred Nobel, spent his final years. There were three main participants: the Europeans, arguing the need for roboethics, the Americans, using robot technology for military purposes, and the Japanese, concentrating on humanoid robots. The symposium saw a direct clash of opinions among these three parties. From the European side, an expert studying the digital divide at the United Nations took the rostrum and set out the position that robots create disparities between people and exacerbate the already present digital divide, criticizing the ill-thought-out introduction of robots to domestic and residential environments as a threat to people's lifestyles, and arguing that they should become cautious about the introduction of robots. The speaker voiced opposition to the American idea of transferring the use of robot technologies to military weapons.

In response to these European opinions, the Americans cited the example of the automatic missile interception system employed on cruisers, and showed their stance that prohibiting the transfer of robot technologies to weapons is not a realistic option. The automatic interception system is a setup in which missile are automatically launched to attack a missile the moment that the system detects a missile approaching, and while somebody has to press a button to initialize the system, no human involvement is required from that time onward. America's argument was that a system that automatically reacts when a certain set of preset conditions coincide is also, after all, a robot. They insisted that robot technologies have already been incorporated into weapons, and American researchers were in no position to sign the sort of declaration demanded by the Europeans. The Japanese side held a different opinion – that the current state of affairs is no more than the earliest days of robot technology, and that it is too early to start talking about the demerits it may cause to humans, or any ethical or moral problems. For the time being, while further developing robot technologies and thinking about in what formats they can be of use to mankind, a robot market will never be fully created unless we establish useful applications for robots.

This is how the First International Symposium on Roboethics drew to a close, with the utterly different perceptions of the Europeans, Americans and Japanese made quite clear. My perception of the differences in the awareness of robots in various countries and regions is that it reveals the differences in

[1] http://www.roboethics.org/sanremo2004/index.php.

their attitudes to robot research and the differences in their research fields. The difference in Japan is probably the prevalence of research dedicated to humanoid robots. In actual fact, it is not uncommon for foreign countries to ask why Japan concentrates on humanoids. I think that the answer to this question lies in Japan's unique national color, and historical and cultural background.

1. 2. *The development of robots in Japan*

Humanoid robot research is flourishing in Japan, with several research institutions involved in research, each with their own goals. I myself, in cooperation with universities, various research institutions and businesses, have worked on research into biped humanoid robots that walk on two legs just like a human, that can play the flute, and can create facial expressions in response to the circumstances surrounding them. Most of this humanoid robot research has taken the form of interdisciplinary projects involving researchers from biology, psychology and medicine, and we are now at a stage in which it is becoming impossible to complete the robots using robotics alone. In the field of research into humanoid robots that walk on two legs for example, achieving a smooth walking motion was an issue, and it was medical knowledge about the human pelvis that was useful in resolving this quandary. The key to humans' smooth walking motion lies in the movement of the pelvis, and incorporating this movement into the humanoid robots enables us to let them walk smoothly. In this, way the current humanoid robot research is looking carefully at the entity of humans as a provider of hints to solve technological problems; it is elucidating human behavior and motility functions, and incorporating these findings in humanoid robot research. This can also be seen as something that essentially characterizes contemporary humanoid robot research. In other words, contemporary humanoid robot research is developing in tandem with the interpretation of the human entity. So what does the study of humanoid robots illustrate to us about humans, what sort of contribution is it making? I would like to try to explain this from my perspective as one who has been involved in humanoid robotic research. There are broadly speaking three main points in humanoid robot research.

The first point is that by creating humanoid robots we can use them in place of humans for experiments to understand humans. For example, when we seek to understand how the pelvis moves when humans walk, it is impossible to predict the movement of the pelvis from the actual walking movement and then suggest a hypothesis. Even if asked to walk without moving his pelvis an actual human will unconsciously move it, and were we to physically force the pelvis to stop moving it world require surgery to fix it to the body trunk, raising serious human rights issues. However, if we can create a humanoid robot with

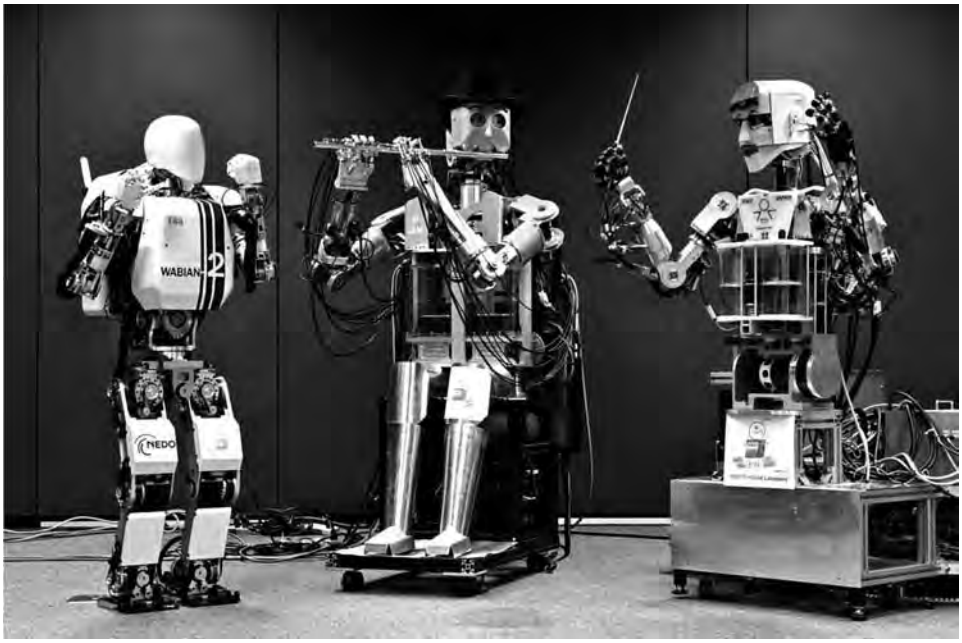

Fig. 1. Various humanoid robots developed by the author and his colleagues at Waseda University.

a similar structure to humans, our hypotheses about the movement of the pelvis can be verified by inputting the data about human movement into a humanoid robot, and it also becomes possible to compare the differences between the robot and the human's walking movements. Another example is the crash test dummies used in vehicle impact tests, a recreation of humans as a piece of hardware. Since the dummies do not have a mechanism like the muscles with which humans move their own joints, the scope for recreating crash scenarios and the scope of experiments in which they can be used are limited. But if we use humanoid robots that can actively move many joints and feature numerous sensors, we can go beyond car crashes to compare differences in the ease of cars' steering, acceleration or braking, and can use them in a wider range of tests than crash rest dummies, thereby obtaining a wealth of data. I call this school of thought that seeks to understand humans from a robotics perspective "robotic human science," but it's a way of thinking that is not actually my own invention. It is an idea propounded by my former mentor, Professor Ichiro Kato.

The second point about humanoid robot research is that by creating robots equippe with a structure like that of humans and using them to recreate movements and behavior similar to humans, we obtain a sophisticated engineering model of humans. In the field of engineering, the basic disciplinary area of physics combines all sorts of theories, such as kinematics, mechanics and

FIG. 2. The late professor Ichiro Kato at Waseda University developed two legged humanoid robots WABOT-1 in 1973 having intelligence such as vision recognition, voice recognition and speech synthesis, etc. (1925-1994).

electromagnetism, and first of all models from an engineering perspective various manmade objects that are the subjects of design and development, like vehicles and aircraft. For example, the design of robot arms starts with the use of kinematics to create a model combining several joints and links for the turning and direct movement of the entire arm; then using kinetics, the links are modeled as a rigid body. The arm's link system is thus completed as an engineering model. Next, using kinetics, the link system is formulized as an equation of motion. Various mathematical analysis methods are applied to the arm, thus expressed as a mathematical formula, according to its projected use or operational purpose, and the types of joint (rotating or direct movement) and their position, the length and mass of the links and so on are quantitatively calculated and decided upon. Though this is already used in the field of artificial intelligence, the same method could also be employed to obtain informatics models not only for the motility functions of humans but also with regard to cerebral functions. So this second point is that since humanoid robots are produced through a process such as this, if we can reproduce in them the various thoughts and behavior of humans it would immediately represent the engineering-based modeling of humans.

The third and final point is the idea that by using the human engineering model arrived through the above-mentioned process, I want to create a robot that can make responses as flexible as a human. This could perhaps be described as a burning desire, rather than a thought. The current robots start to perform badly if they become even slightly derailed from their preconfigured conditions. Simply changing a floor surface from synthetic wood to a carpet necessitates the reconfiguration of their systems. In comparison, humans are remarkably flexible. Humans have given birth to words and characters, and even raised them to the heights of literature; Olympic athlete display an almost unimaginable way of moving. As a robot maker, I have the feeling that

I want to make my robots move freely – that is the spectacular and grandiose nature of the challenge.

What kind of contribution to contemporary society will humanoid robot research go on to make? Examples of some applications resulting from biped walking robots would include, as a replacement for traditional wheelchairs, two-legged chairs, which could without any difficulty climb and descend staircase, and would probably be useful in narrowing the gap between able-bodied and disabled people. Elsewhere, research into humanoid flute-playing robots has numerically converted the way that the lips and tongue are used when performing – something that people have to learn through a process of trial and error – and made it possible to recreate these movements. Moreover, this research has shown that human flute performances include an inherent fluctuation in the way that breathing is used and that it is through this fluctuation that a performance is endowed with humaneness and can be enjoyed as music. Humanoid robot research is, in other words, not merely a question of securing the reproducibility of a piece of apparatus or a machine's safety; it enables us to elucidate from what factors the sensuous reactions such as inorganic texture and humaneness arise. By understanding these sort of questions, there can be no doubt that we will go on to discover how to reduce the stress of being surrounded by machinery, and provide peace of mind.

But what of the humanoid robot developments at institutions other than my own, or that carried out by other researchers? Currently, research and development efforts concerning humanoid and animal-like robots are flourishing in Japan. The companies involved in robot R&D in Japan include brands famous not only in Japan but throughout the world, such as Toyota, Hitachi, Honda, NEC to name but a few. Moreover, government agencies such as the Ministry of International Trade and Industry and the Japan Science and Technology Agency participate enthusiastically, and humanoid robots are developed without the slightest trace of aversion.

From a historical perspective, though this depends on what one's definition of a 'robot' is, Professor Ichiro Kato was probably the first person in the world who started to work on humanoid robots. His work began in 1970, and in 1973 he completed WABOT-1, the world's first full-scale humanoid robot, and in 1984 WABOT-2, a musical robot capable of playing keyboard instruments. According to Professor Kato, in 1970 when he was launching his work on humanoid robots, another engineering professor criticized him, saying: "There's no way that a two-legged metal robot is going to walk. You ought to stop this pointless research." Though these were dark times for researchers, nobody now criticizes the technical side of robots, and the field has even become a major industrial area that major manufacturers queue up to participate in.[2]

[2] http://www.humanoid.waseda.ac.jp/index.html.

With many of Japan's most famous companies enthusiastically taking part in the development of robots, it would seem that in Japan robots are something to be admired rather than criticized. While there was initially some criticism of Professor Kato during the early days of robot development, the decisive difference in the nature of the present European criticisms surely lies in the fact that it was directed against the likelihood of his work being technically feasible, rather than being an ethical or moral indictment. The majority of the criticism of humanoid robots sometimes seen in Europe and America is directed against changes in human society caused by the emergence of humanoid robots, and concerns religious taboos.

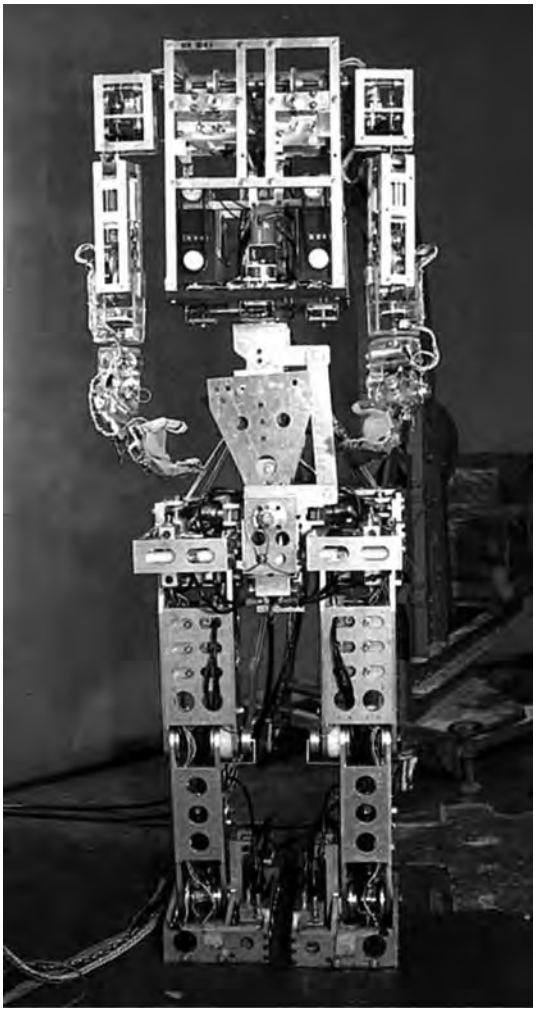

FIG. 3. WABOT-1 which stands for WAseda roBOT developed by Professor Kato and his colleagues realized two legged walking, paper cup grasping by stereo vision processing, and verbal communication with a human by voice recognition and synthesis in 1973.

On the other hand, the great interest of the Japanese people in humanoid robots is unique. Moreover, the greater share of this interest tends to be favorable, and the Japanese are actually looking forward to progress in humanoid robots rather than opposing them. Looked at from the view of the Europeans and Americans who are calling for roboethics, this no doubt appears rather bizarre. I will now turn to this situation, a situation in which the Japanese concepts and orientations regarding humanoid robot R&D differ from those of the European and Americans.

2. The background to the advent of knowledge and manufacturing technology in the nation of Japan

2. 1. *Japan was historically a peaceful nation*

Looking back over Japanese history, in terms of historical substance one could probably point out the fact the emperors, the symbol of Japan, have succeeded each other by descent from the ancient days to the present time. All around the world, in almost every nation the monarchy has drastically changed according to the powers of the time. But what about Japan? According to the Chronicles of Japan, compiled in the first half of the 8th century, the history of the Japanese emperors can be traced back to the first emperor, Jinmu, who ascended the throne in 660 BC. Right up to the present day, a single imperial family has ruled Japan without interruption for around 2,600 years. Though Japan has witnessed the chaos of civil wars from time to time, the fact that it has never experienced conquest by an outside force is surely one of the nation's unique characteristics. The period that really demands our attention is the Edo Period – the age leading up to the Meiji Restoration when Japan opened itself up to the world as a modern state – during which Tokugawa Ieyasu founded the Edo Shogunate.

The Edo Period started in the year 1603, when Tokugawa Ieyasu launched the Edo Shogunate, and lasted for another 260 or so years until Japan's closed nation policy was ended by the arrival of Commodore Perry and his fleet,[3] and the Japanese industrial revolution established by the Meiji Government started in 1868. In 1615, Tokugawa Ieyasu made a groundbreaking move. He routed his enemy, the Toyotomi clan, and at the time as ending the era of civil war he issued ordinances including the *Buke Shohatto*, a code of conduct for samurai clans, which sought to prevent any further armed clashes inside of Japan.[4] Put in simple terms, he forbade any kind of technical development related to weapons. The ordinances were extremely effective, and in the 250 years before the end of the Edo Period there were no major armed internal conflicts in Japan. Since the samurai were forbidden from using weapons, they had no choice but to shift the swordsmanship they had built up towards the direction of the more psychological pursuits of kendo and martial arts. Because Ieyasu also forbade the use of the pistols that had come from Portugal and spread across the country, gunsmiths lost their jobs and became fireworks makers instead. It is from this episode that the popularization of fireworks in Japan during the Edo Period stems. In this way nearly all the people involved in military purpose industries such as mining and manufacturing drifted into other industries, and the majority of them are believed to have moved on to

[3] http://en.wikipedia.org/wiki/Matthew_C._Perry.
[4] http://en.wikipedia.org/wiki/Buke_shohatto.

the leisure and construction industries. Until then, the clandestine and autonomous development of military technologies among the ruling families of the regions had not been unexceptional. The result of all this was that nearly all of the economic and technological activity of the period became peace-oriented, and wide and varied academic learning and culture blossomed. This is why the learning and cultural fields of the Edo Period reached an extremely high level, with the introduction too of excellent technologies. While the 1600s saw the people of Europe dominating the world with their military prowess, Ieyasu altered the course of Japan in the direction of a political system that did not rely on military strength. There is an interesting entry in the report that Commodore Perry submitted to the American government in the final years of the Edo Period.[5] When Perry, who regarded Asia as a potential colony, arrived in Japan, apparently he gained an impression of the country that differed from the way he had viewed other Asian nations. In particular, he pointed out the cleanliness of the Edo towns. With regard to the daily lives of the ordinary people, he commented that he did not at all think that the ruling samurai and bureaucratic class oppressed the public. He even predicted that, referring to the arts and crafts of Japan, in the near future the country would maybe become a top class industrial nation.

The popularization of the arts, that had permeated Japan to such an extent that they were enjoyed by the man on the street, was supported by the *terakoya*. The *terakoya* were educational facilities established in the Edo Period for the sake of the general public. The teachers were predominantly local priests, doctors and samurai, and the students learnt reading, writing and how to use an abacus, geography, and the names of people and the manners requisite in everyday life. Most of the schools were mixed gender, and it is thought that there were around 1,500 in Edo and 15,000 nationwide. Long-term education was provided for students, who entered the *terakoya* at the age of five and left between the ages of 13 and 18. Moreover, the entry rate to the *terakoya* was very high, with records showing that around 80% of ordinary children in Edo attended one during the final years of the period. It was the *terakoya* that fostered a literacy rate in Japan that was in those days among the highest in the world. The abacuses served not only as a tool, but also led to sophisticated mathematics as children learnt how to use them. The best-selling mathematics book of the time, the *Jinkoki*, began with four-function calculations, clearly explained sentence-based problems, and the calculation of area, volume and tax, and eventually enabled the student to understand

[5] Narrative of the Expedition of an American Squadron to the China Seas and Japan found at http://ebook.lib.hku.hk/CTWE/B36599566/.

geometry.[6] Japan's[7] mathematics subsequently developed into a uniquely Japanese version of the discipline, and became a field that treated extraordinarily sophisticated geometrical problems. And every time a mathematical question or problem was solved, a dedication was made at a shrine or temple as a *Sangaku* meaning Mathematics Tablet in English where the solution of the problem was described.[8] Knowledge[9] was regarded not as something to be fenced in, but to be spread and popularized. Takakazu Seki was one of the people who contributed to the development of Japanese mathematics, leaving a mathematical legacy comparable to that of European mathematicians, including the discovery of the approximate value of circumference ratios, and Bernoulli numbers.[10]

Japan, with its high literacy rates and excellent calculating skills, lagged far behind Europe and America in military terms, partly because of the peaceful school of thought that it had inherited from the Edo Shogunate. The fact that Japan submitted to Perry's insistence on opening up the country has been explained by the nation's total inability to do otherwise in the face of America's military might. However, there is also a school of thought arguing that Ieyasu's restrictions on military industries encouraged the diversion of technology towards other sectors such as the leisure and construction industries, contributing to a high level of knowledge among the people, and decisively avoiding the colonization of the nation by America. The industrial revolution sparked by the Meiji Restoration boosted the industrialization of Japan and also led to the experience of several wars. However, the way that Japan has not been invaded by another nation, even after the end of the Second World War, and has once again returned to a philosophy of peace, is indeed a strange twist of fate. Surely it is plausible that the background described above has had some sort of impact upon the sense of trust that the Japanese nation has in technology.

2. 2. *The development of the karakuri resulting from mechanical technology*

Edo culture developed considerably with the flow of military technologies to other industries such as mining and manufacturing, and one such cultural phenomenon was the *Karakuri*.[11] The *karakuri* is often confused with pup-

[6] M. Yoshida, S. Kenichi, *Jinkohki*, first published edition, Kenseisha, 2006 (Translated to current Japanese).

[7] S. Seyama (ed.). *Math is Fun*, «Nikkei Science Additional Volume», «Nikkei Science», 169 (2010), (in Japanese).

[8] http://www.wul.waseda.ac.jp/kotenseki/search.php?cndbn=%8Bg%93c+%8C%F5%97R. [9] 10 http://en.wikipedia.org/wiki/Sangaku.

[10] http://en.wikipedia.org/wiki/Seki_Takakazu.

[11] http://en.wikipedia.org/wiki/Karakuri_ningy%C5%8D.

pets, but puppets are dolls whose movements are directly manipulated by a person using a thread, whereas the *karakuri* has a thread or similar gadget concealed internally, and moves without the manipulation of a puppeteer. The *karakuri* included numerous variations, some of them containing a mechanism to move the doll inside, some in which the doll was attached to a stand, and some of which were incorporated into the floats carried at festivals. Their history is long, dating back to the Heian Period between the 9th and 11th centuries. Moving into the subsequent Muromachi Period between the 14th and 16th centuries, in tandem with the arrival of pistols and clocks from the West, *karakuri* featuring complicated mechanisms driven by weights and springs started to appear, but it would not be until the Edo Period that fully-fledged *karakuri* combining several types of complex mechanisms arrived. This was due to the fact that during the years of civil war before the Edo Period most of the engineers were preoccupied with the development and manufacture of weapons.

FIG. 4. Terakoya school in Edo period taught not only written language but also mathematics for children in any social classes such as the samurais, farmers, engineers and the merchants.[12]

Because Japan isolated itself from the outside world as it entered the Edo Period and cut off all exchange with foreign countries, it provided the Western nations with a huge advantage in terms of the technologies related to mining and manufacturing and the military industry, particularly large-scale devices

[12] http://en.wikipedia.org/wiki/Terakoya.

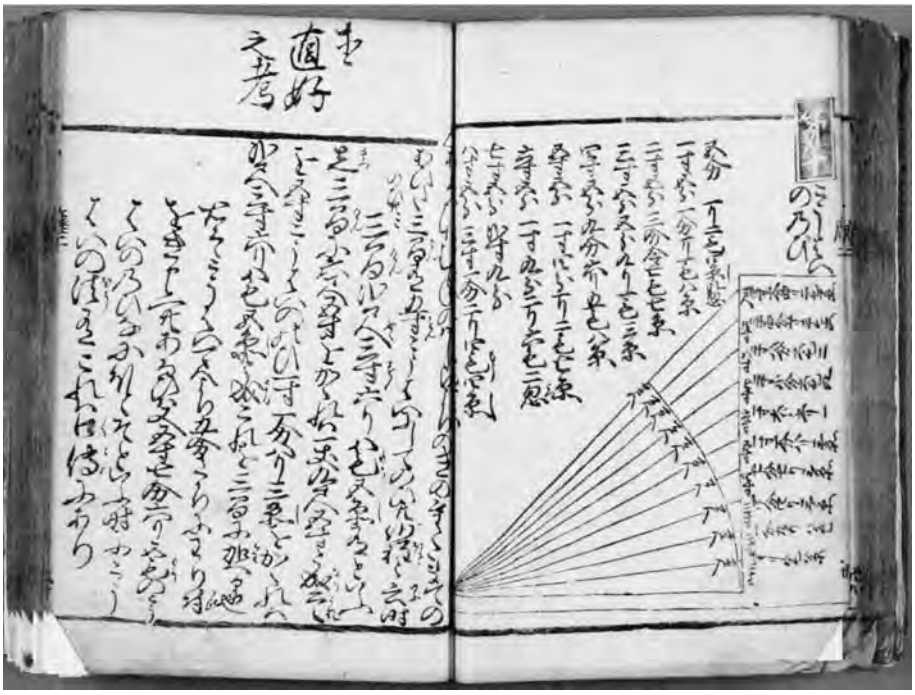

Fig. 5. Jinkoki is a text book for teaching mathematics at Terakoya schools in Edo period in Japan[8].

Fig. 6. This is a Sangaku, which means mathematics tablet, showing solutions for three mathematical geometry problems solved by Genjiro Tomimura dedicated to Enmanji temple in Nara city in 1844[10].

and machinery typified by the steam engine, and the metal processing technologies required for the manufacture of such goods. However, as I have already mentioned, in terms of areas such as learning and culture Japan enjoyed standards quite comparable to those of Western Europe. The same can be said for the *karakuri*. The *karakuri* of the Edo Period were one of the pleasures that caught the eye of the general public, and their provision was an opportunity for the engineers of the time to display their prowess. The very latest technologies were incorporated in them, not merely to satisfy the members of the general public who visited sideshows, but to amaze the feudal lords and aristocracy assembled in Edo; *karakuri* evolved to become evermore precise, evermore skillfully made. This is why it is said that looking at the Edo *karakuri* shows the scientific and technological level of the period.

Fig. 7. Tea serving Karakuri is a doll which serves a cup of tea on its arms to a people by coming towards the front then returns to its starting position when the tea cup is put back to the arms[12].

Now let's take a look at the *karakuri* in Western Europe, where there was a similar device known as an automata. The automata's roots are thought to be an automatic door developed by Heron of Alexandria, a Greek engineer, in the 1st century BC. This door featured a mechanism in which the temple door opened when a light was lit on the altar, and closed when it was extinguished. Automata subsequently spread to manmade gardens and mechanical clocks, and some time around the 15th century mechanical animals and dolls started to appear, evolving into extremely precise figures in the 18th century. These automata wrote, drew, or played the piano. And some of them could even be altered to change what they wrote, drew or played, by adjusting their internal mechanisms. In fact, this is the major difference between automata and *karakuri*. The point of the automata is, once it has started to move, just how precisely and ingeniously it can do so before it stops. The automata performing pieces of music are a good example of this. In contrast, the Edo *karakuri* tend to emphasize their interactive aspect, and in this way they differ from

the automata. For example, there is a *karakuri* in which a figure carrying tea will not move just by having its spring wound; the figure has to have a cup filled with tea place upon its palm before it will move. The figure uses this human action as a trigger to start to place the tea before the "guest," and finally ceases to move once it is in front of the guest. The movements of the figure restart when the guest takes the tea from the figure's hand, then drinks it, and replaces the empty cup in the figure's hand. This sort of mutual interaction between humans and the dolls is something unique to the Edo *karakuri*, and unknown in the Western automata.

In addition, there was another aspect of these *karakuri*: the way that technology was transmitted. Technology had since the old days been something that was handed down by master craftsmen in Japan, in a way that could be described as an apprenticeship system. The *karakuri* were, however, an exception. The first makers of *karakuri* in Japan include many names such as Omi Takeda, who opened a sideshow in Osaka, Igashichi Izuka, Benkichi Ohno and Hisashige Tanaka, but none of these men had a master *karakuri* maker to look up to. The question of upon what their creation of *karakuri* was based is thought to lie in the *Karakurizui*, a book published in 1796 during the latter half of the Edo Period. The author, Hanzou Hosokawa, introduces four types of clock and nine types of *karakuri*, including the tea-carrying *karakuri* that is described as the zenith of Edo *karakuri*. Moreover, what are especially interesting in this book are the descriptions of clocks and the operational and production methods of *karakuri*. Using draftsmanship that would not be out of place in the present day and age, the author describes in detail the shape of every component, the precautions required in their manufacture, the order in which they are assembled and so on. By reading and understanding the Karakurizui anybody now can make a clock or *karakuri* incorporating technologies that were the very latest at the time of writing. The book is similar to the articles on manufacturing processes nowadays seen in engineering magazines, and was an epoch-making publication in the sense that a reading of it enabled anybody in the Edo Period – a time when the apprenticeship system was prevalent – to master precisions technologies on their own.

In addition to the *Karakurizui*, there was another famous collection of design diagrams – the *Karakuri Kinmokagamigusa*, which was written in 1730 by Kanchusen Tagaya.[13-14-15] The book predates the *Karakurizui* by some 66 ye-

[13] K. Suzuki, *Karakuri Dolls – Edo Period Technology Hidden in the Doll's SmGigaile*, Gakushu Kenkyusha, 1997 (in Japanese).

[14] K. Tagaya, Y. Hosokawa, T. Kikuchi (Introduction), *Kinmokagamigusa/Karakurizui*, Kowa Shuppan, 1976 (in Japanese).

[15] S. Tachukawa, S. Tanemura, S. Tamaya, K. Aoki, A. Takayanagi, *Karakuri - An Illustration*, Kawade Shobo Shinsha, 2002 (in Japanese).

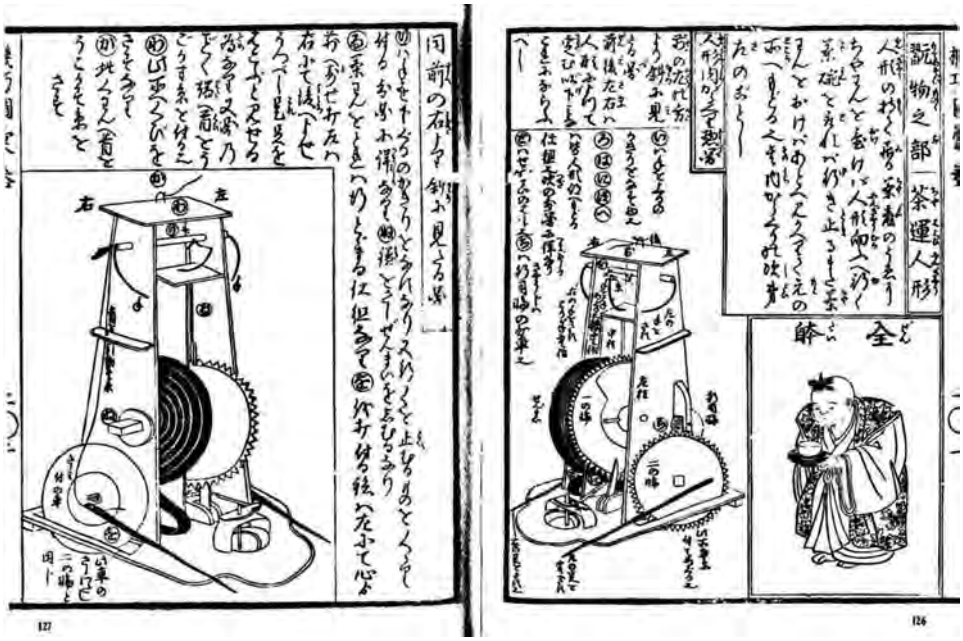

Fig. 8. Karakuizui is a text book describing how to build Karakuris by showing many assembly drawings written by Hanzou Hosokawa in 1796[14].

ars. The difference between the two volumes is probably that while the *Karakurizui* describes the production of *karakuri*, the *Kinmokagamigusa* finishes with an explanation of their principles. The earlier part of the *Kinmokagamigusa* is a textual and pictorial compilation of views of the itinerant *karakuri* performances taking place around the country, in a picture book format. The latter half of the book is taken up with an explanation of the principles of the mechanisms that made the *karakuri* move. The principles of karakuri were mastered from *Kinmokagamigusa*, and the technical knowhow from *Karakurizui*. A combination of principles and knowhow are still vital for engineering students in the present day, and it would be fair to say that the handing down of technology through books was established during the Edo Period.

2. 3. *The emergence of robots in manga and animation*

The manga, a Japanese traditional art, has a very old history, dating back to what is believed to be the oldest example, the Choju Jinbutsu Giga (a set of scrolls depicting caricatures of animals) drawn some time around the 12th century. The scrolls caricature rabbits, frogs, monkeys and so on, depict imaginary creatures such as dragons and mythical lions, and tell a story through pictures.

Fig. 9. Karakuri Kinmokagamigusa is a text book describing the disciplines of many Karakuri mechanisms by written Hanzou Hosokawa in 1730.

In Japan, the portrayal of animal caricatures living side-by-side with people in society is not at all uncommon, be it in manga or old folk stories. Moreover, it is not only animals that are caricatured in this manner. In addition to the fantastical creatures shown in the Choju Jinbutsu Giga, even tools such as mortars and pestles are anthropomorphized. Since ancient days animals and objects other than humans are featured in Japanese tales – both as allies and foes – and the humans, without a bat of an eyelid, have accepted their appearance. These tales became colored woodblock prints and engravings during the Edo Period, and were popularized as one of the pleasures of the general public. It is said that the spread of manga in Japan was the result of the high levels of literacy among the Japanese, including the general public. There are documents suggesting the literacy rate in Japan during the 18th century was around 80% compared to about 20% in Western Europe. In Japan, a story was something to be enjoyed in both words and pictures. Moreover, some of these anthropomorphized creatures walked on two legs and were the subject of considerable distortion. These modes of expression were subsequently passed on to future generations.

In later years, Japanese manga expanded their mode of expression to animated films with the advent of the diffusion of television. Let's now consider

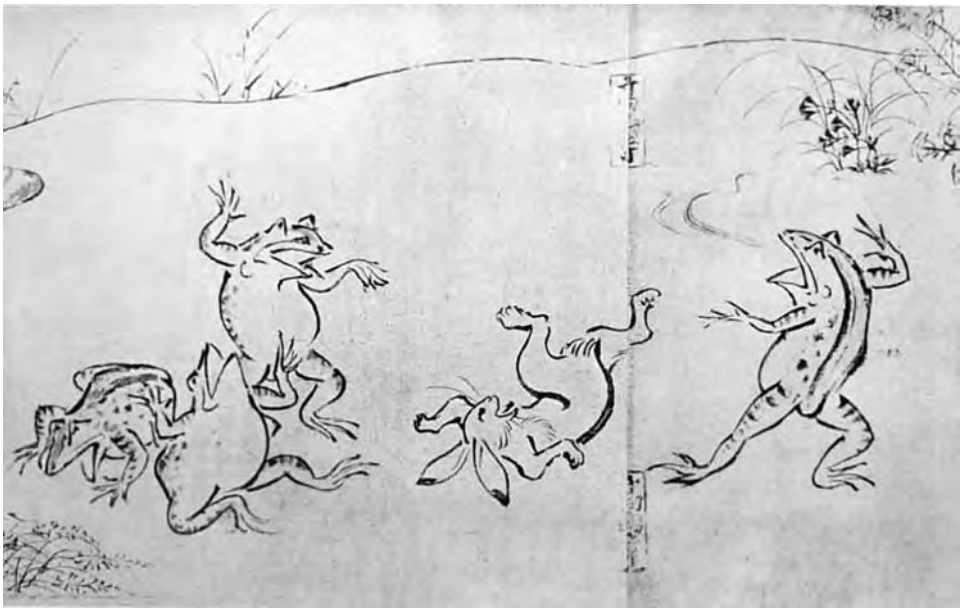

FIG. 10. A part of Choju Jinbutsu Giga owned by Kozanji Buddhist temple in Kyoto, Japan meaning Animal-person Caricatures where animals are playing sumo wrestling at a celebration is the oldest Manga drawn in the 12th century in Japan.[16]

two of them, Osamu Tezuka's *Astro Boy*,[17] and Mitsuteru Yokoyama's *Tetsujin 28-Go*.[18] Both stories deal with the subject of robots, and *Astro Boy* in particular was Japan's first domestically produced television animation. What is interesting about this is that while Osamu Tezuka's original interest in animation started with Disney, the hero of this first-ever Japanese animation was a robot. Despite being influenced by the films of Disney, with their image of animals and fairies, Tezuka used a robot for the main star role.

Furthermore, the simultaneous release of *Astro Boy*, and *Tetsujin 28-Go* is also intriguing. The fact is that while they both deal with the topic of robots, the personalities of the two robots are utterly opposite. Astro Boy is an autonomous robot. He himself controls his actions through the computer that he himself had installed within his body, and he alone decides upon how he will act according to the situation and the people around him. On the other hand, *Tetsujin 28-Go* is the complete reverse – a robot that is tele-controlled by other people. We can categorize the contemporary robots under development into two types: the autonomous robot and the tele-controlled robot; both types appeared at the dawn of animated films.

[16] http://en.wikipedia.org/wiki/Ch%C5%8Dj%C5%AB-jinbutsu-giga.
[17] http://en.wikipedia.org/wiki/Astro_Boy.
[18] http://en.wikipedia.org/wiki/Tetsujin_28-go

3. The influence of a unique religious view and historical culture

3. 1. *A non-materialist national sensibility*

There is a decisive difference in the religion of Japan compared to that of the Western nations. Whereas the latter follows a religion based on a single deity, Japan is polytheistic. Perhaps because they think that monotheism is the standard practice throughout the world Western people have a suspicion that the Japanese are Buddhists, but the Japanese themselves do not actually feel so. In fact, in terms of religion it is Shintoism that has had the greater influence in Japan.[19] Shintoism sprung up spontaneously among the people living in Japan islands, and has no clear creed or scripture. Shintoists believe that gods exist throughout the universe, and as the phrase for their collective name, "eight million gods" suggests, rather than being a single deity they are to be found everywhere – in people, animals, trees, water and elsewhere. Looked at from the polytheist stance of Shintoism, Buddha and the other Buddhas can be treated as just some of these eight million gods. In this sense the Japanese view of religion, which has accepted Buddhism while also showing an appreciation of Christianity, is based on a perception that "God" does not equate with a single creator, and has essentially inherited the polytheism of Shintoism.

Fig. 11. Munakata Taisha is one of the oldest Shinto shrine in Japan located in Munakata city, Fukuoka prefecture that has second largest number of national treasures in Japanese shrines and some of the treasures are more than two thousand and several hundred years old.

[19] http://en.wikipedia.org/wiki/Shinto.

Just as physicists accept superstition, in high-tech factories and so on an altar in which talismans dedicated to a god (such as the god of safety) are placed is often built somewhere on the facility in order to pray for safety. These practices are carried out regardless of the size of the company, with such altars in the factories of Toyota, the vehicle maker, Kanebo, the chemical maker, and often at the overseas factories of Japanese companies with a global presence. Asking the gods for help has in this way permeated Japanese culture. On a personal note, I have noticed that on one of the two-legged robots for carrying people that we produce somebody, probably the students in the laboratory attached a good-luck charm from the Munakata Shrine. It was a wish for the safety of the robot made with the same ease as a person praying to the gods that their own car will not meet with an accident. Perhaps behavior such as this arises from the fact that, for Japanese people, their omnipresent gods are much nearer to them in comparison to the distance between Europeans and Americans and their single God.

3. 2. *The Japanese, approaching everything with a feeling of gratitude*

The Broken Needle Festival is one of the extant practices surviving from the ancient days. On the annual day of the festival, sewing needles that have snapped or become bent over the past twelve months are collected and prayed over in a sense of gratitude for their service thus far. The rats, mice and other animals used in experiments are also the subjects of commemoration. It is common for a small shrine to be constructed within the grounds of many facilities, where the spirits of the animals that have died in experiments are commemorated each month. These activities are not limited to just needles and the animals used in experiments.

These acts may be unthinkable in Western Europe. In Japan there is a culture in which simple "things" that have become unusable turn into objects of gratitude and commemoration, sometimes even having tumuli prepared for them and becoming places of devotion. This is not totally unrelated to the fact that the Japanese believe gods are at work everywhere. It is a view of the world explicitly based on the concept of everything containing life. Ethnographically speaking there are similarities to animism, but this culture passed down from antiquity continues to be transmitted despite modernization, and is a view of the world that sees life in every object.

Wangari Muta Maathai, a Nobel Peace Prize winner, paid particular attention to the Japanese phrase "mottainai," a word in which the Japanese worldview is contained. It is often suggested that the word means no more than the English expression for "waste." Admittedly, it is indeed the same as "waste" in the sense of something that has lost its potential or functions is of no use, but in fact the phrase is a belief that the object in questions still has some sort

of future. The word "mottainai" can be used for both objects and people, and it contains a sense that the precious life within either will be wasted. In other words, with the precondition of a feeling of the presence of life throughout everything, "mottainai" encapsulates a fierce criticism of this life being wasted.

Looking at the Japanese views of religion and the world suggests that is these that are at the root of how they see life in simple objects. Behaving as if inanimate objects have life could be rephrased as an utter inability to treat things in a careless way, because they all contain life. Surely if this spiritual culture is translated into the scope of behavior, a highly ecological way of behaving would be seen. It is 'mottainai' that puts this into words. Recent research shows that thorough recycling was carried out during the Edo Period, not because the Japanese are thrifty, but probably because, since they saw life in objects, they pursued the question of how they could continue to use them. Old kimonos would be cut up to make facecloths, the face cloths would eventually be recycled as dusters, and the dusters would finally be burnt and the ashes scattered on the fields as fertilizer. From clothing to facecloth, to duster to ashes – it was simply that they saw life in these objects and treated them carefully, and they certainly had no idea that they were carrying out 'recycling.' They merely wanted to be careful with animate objects.

3. 3. The distinction between organic and inorganic

To the Japanese, with their belief that there is life in everything, the border between the living and the dead is extremely vague. They think that there is life even in inorganic substances, and quite naturally so. In contrast, the Western view of death appears to have quite clear boundaries. The criteria for brain death are an example. It is widely perceived in Western Europe is that the death of the brain is the death of that person; even if their heart is beating and beads of sweat from on their skin in the heat, once their brain is certified as dead they are corpses. If somebody else needs them, their hearts, livers, kidneys and eyeballs can be donated. The perception is that the corpse before them is a person who "was once alive." The Japanese simply can't understand this. The Japanese, with a worldview in which they can see life even in a stone lying by the wayside, find it difficult to accept brain death. It is now over ten years since transplants from brain death patients were permitted, but only about 100 organ transplants have taken place. One can understand the way that the Japanese are somehow reluctant towards brain death compared to say Germany, a country where there is a heart surgeon who has performed more than 1,500 heart-transplants.

The objects lying in the space between the philosophy that that there is life in inorganic objects, and the philosophy that it is only organic objects in which there is life. These are the differences in thought between the Japa-

nese and Western peoples. The Japanese do not think that if something has life it is organic, or if it has a human shape it is human. It has life even if it is not organic, and just because it is humanoid doesn't necessarily mean that it is human.

3. 4. The Japanese use of the brain

The Japanese view of religion and the world is a culture, and probably what this environment that we call Japan is. Apart from spiritual influences, what sort of physical effects are exerted by, for example, the functions of the brain? Some interesting research has been reported regarding this point, namely the research into the processing of sounds by the brain functions. The brain ordinarily consists of the left brain and right brain, of which the left is thought to be deeply involved with logical thinking, procedural thoughts and language. The right brain is believed to capture images of objects through sensations, and have a profound involvement in the visual images and sounds. To give a concrete example, when people listen to conversations, speech, lectures or other intelligible spoken voices it is the activity of the left brain used to deal with language that is stimulated. On the other hand, it is thought that it is the activity of the right brain – dealing with images and sounds – that is stimulated when we hear sounds such as music, or the sounds of instruments and mechanical noises. There are no apparent differences between the Japanese and Western people with regard to these brain functions.

However, when Tadanobu Tsunoda compared people living in Japan and those living in Western Europe he showed that there was a difference in the active parts of the brain with regard to the sounds of crying and laughing, the cries of animals, the sounds of waves, wind and rain, and the sounds of rolling stones and rocks. When those living in Western Europe hear these sounds the right brain dealing with images and sounds becomes active, but it is the left brain responsible for language that is stimulated in the case of people living in Japan. In other words, when those living in Japan hear these sounds it is the area of the brain processing language that is activated. Their brains perceive them not as sounds but as language.[20] Moreover, when Koreans, who speak a language that is morphologically grouped with Japanese as being agglutinative, were compared, only those Koreans who lived in Japan heard these sounds with the left brain. In addition to research on this topic using brain waves, research has also been conducted using magnetic resonance imaging (MRI) as well as other follow-up studies, but it certainly appears to be a phenomenon found only in Japan.

[20] T. Tsunoda, *The Japanese Brain: Uniqueness and Universality*, Taishukan Publishing Company, 1985 (Translated by Yoshinori Oiwa).

In fact the way that the left brain becomes active when the sounds of people and animals crying or the wind are heard, in other words when these are heard as language, is not something unique to the Japanese race or Asians. Tadanobu Tsunoda, who focused his attention on the workings of the brain, pointed out that the factor behind this characteristic was not race but environment. He has published a research paper indicating that people, particularly those who live in Japan from birth to the age of nine, exhibit this characteristic regardless of ethnic origin. Tsunoda has also suggested that with regard to the unique view of religion and the world of the Japanese there is a correlation between the Japanese views of nature and sentiments, and the environment of Japan in which they live. He has put forward the hypothesis that among the environmental factors leading to this characteristic, spending the nine years after birth in the linguistic environment of the Japanese language is particularly influential.

The suggestion that once inside the environment of Japan the brains of people, regardless of their race, perceive when they hear them "sounds" – such as cries, the calls of animals, the sound of the wind and falling stones – as language, is reminiscent of the relationship between the Japanese people who feel life in everything, and their worldview. Perhaps, the way that the brain perceives sounds as language when hearing them could be described as a subconscious effort to try to read some sort of message in these sounds. Taking this idea another step further, feeling some sort of consciousness or presence of life in these sounds or the people or objects from which they originate may not be such an outrageous thought.

4. Conclusions

4. 1. *The diversity seen in humanoid robot development*

In the light of Japan's abundant humanoid robot research, I am often asked by Western robot researchers whether or not there is any social criticism of humanoid robot research in Japan. As a Japanese researcher this is not an easily answered question. Because if there are none of the religious taboos that lies behind this question, in other words, the taboo that man is made by and given life by God, and it is blasphemous for men to create humans, even if there is a consciousness of making something resembling a human, we do not think that we are making humans. Rather, the more time I spend on humanoid robot research the more I find myself face-to-face with the profound complexity of the human entity, and the larger is my self-regret that I am still technologically such a long way from making a robot with the same functions as humans. This is why I see the creation of humanoid robots as such a grand challenge. Apart from the technical aspects, all that I can say in response to the Western robot researchers is that probably I am spurred on by a wish to

explore that something that isolates man from machine, that something that we do not yet understand.

Reminiscent of the Japanese *karakuri* are the Western European automata. It is in the automata that the concept of wanting to create something the same as a human is more clearly displayed. The proportions and form of these are closer to humans than those of the *karakuri*, and one can feel the technicians' desire to achieve this proximity in form. In Japan, by contrast, it probably doesn't matter if the finished article is not exactly like a human; so long as it is humanoid, the viewer can project something "humane" on to it. Can it not be said that it was the environment of Japan that nurtured this?

I think that the rarity of any Japanese antipathy towards humanoid robots is related to the fact that the Japanese do not have the taboos that Westerners feel or expect others to feel. However, I think that the fact that we Japanese do not share these taboos is not because we are Japanese, but because we have lived in the environment of Japan we simply have never acquired them. It is like the diversity of the knowledge that we have built up since antiquity over the space of 2,600 years, in a society and environment unlike that of Western Europe, and free from foreign invasion. The rarity of antipathy towards humanoid robots is not merely an excuse for pushing ahead with their development. As a person cultivated in the environment and culture of Japan, there is no more that I can say.

Abstract: *The author describes three different positions with regard to robotics: the European, American and Japanese. It focuses on the current Japanese and presents an historical overview, from early automata from the XVI-XVII century to the present day. The Contemporary Japanese scientists are focusing on the production of humanoid robots. According to the author, the creation of anthropomorphic robots helps to question deeply and effectively about the nature of human beings.*

Keywords: *humanoid robotics, technology, roboethics, Japanese technology.*