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Intersection of "Tokku" Special Zone, Robots, and the Law: A Case Study on Legal Impacts to Humanoid Robots

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Abstract The unique *"Tokku" Special Zone for Robotics Empirical Testing and Development* (RT special zone) originated in Japan. Since 2003, the world's first RT special zone had already established in Fukuoka Prefecture, Fukuoka City and Kitakyushu City. At that time, Takanishi Laboratory, Humanoid Robotics Institute of Waseda University had conducted many empirical testing within several different spots of the special zone to evaluate the feasibility for bipedal humanoid robots on public roads from 2004 to 2007. It is also known as the world's first public roads testing for bipedal robots. The history of RT special zone is merely 10 years long, but there are already many special zones established in Fukuoka, Osaka, Gifu, Kanagawa and Tsukuba. As the development of robotics and its submergence to the society expand, the importance of RT special zone as an interface for robots and society will be more apparent. In this paper, our main focus is to view the impacts of the "Tokku" special zone system to the human-robot co-existence society. We would like to make a systematic review for RT special zone, and further to investigate the relationship between RT special zone, robots and the law through a case study on legal impacts regarding bipedal humanoid robots in which the materials for the case study come from Waseda University's experiment on WL-16RII and WABIAN-2R at the Fukuoka RT special zone.

Keywords Regulation of robotics · Robot law · Human-robot co-existence · Empirical legal studies · RT special zone · Humanoid robots

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1 Introduction

From a global perspective, conflicts between advanced robotics and existing regulations have risen. Specifically, due to the uncertainty of machine safety and legal liabilities, traffic laws of most countries are not prepared to allow the practical usages and implementations for service robots and self-driving cars.

However, places where next-generation robots perform their duties are not closed structured environments such as factories but open environments where humans coexist. It is unreasonable to ask a robotics manufacturer who creates open environment adaptable robots to produce robots that cannot be tested in public areas during development. This would reflect a contradiction between technical and social artifacts from the socio-technical systems perspective. Thus, a compromise by Japan previously was to divide the *"Tokku" Special Zone for Robotics Empirical Testing and Development* (RT special zone) from open environments.

As the "Robot Kingdom", Japan has a relative lead in robotics technology. Therefore, some social impacts of

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advanced robotics in real society can be found there. The unique RT special zone originated in Japan. It is necessary to certify ethical, functional and safety aspects of the service robots in order to fully realize its potential of co-existence with humans. However, the implementations of these social aspects certification is very limited at laboratories without ample amounts of empirical data. Thus, it is difficult for us to develop regulations for service robots.

One dilemma for the development of service robots is the lack of specific guidelines for next-generation robots leads to uncertainty of pre-safety regulations and post-safety liability distribution. This barrier causes a delay in the competitiveness of the whole RT industry.

The major purpose of the Japanese government to set up this special zone system is to enhance industrial competition from over-regulation. In addition, the establishment of RT special zones are based on authorization from *The Law of Special Zone for Structural Reform* and *The Comprehensive Special Zone Act*. The main function of RT special zones is to conduct practical testing related to RT research and development, especially on the realization of RT experiments on public roads. Related special measures include *The Measure for Facilitating Robots' Experiment on Public Roads*, *The Measure for Manned Mobility Robots' Empirical Experiment on Public Roads* and other revised traffic regulations. However, it is not just limited to these, the RT special zone has other functions such as "Building anchor points for RT startups", "Supporting government-industry-university collaborations that are cross-administrative", "Gathering robotic researchers" and "Developing youth scientific RT education".

Since 2003, the world's first RT special zone had already established in Fukuoka Prefecture, Fukuoka City and Kitakyushu City. At that time, Takanishi Laboratory, Humanoid Robotics Institute of Waseda University had conducted many empirical testing within several different spots of the special zone to evaluate the feasibility for bipedal robots on public roads from 2004 to 2007 [1]. This is known as the world's first public roads testing for bipedal robots. The history of RT special zone is merely 10 years long, but there are already many special zones established in Fukuoka, Osaka, Gifu, Kanagawa and Tsukuba. As the development of robotics and its submergence to the society expand, the importance of RT special zone as an interface for robots and society will be more apparent.

There are three main reasons for us to select the Fukuoka RT special zone as the object of our case study. First, Japan's first RT special zone was established in Fukuoka. Also, the world's first bipedal humanoid robots practical testing on public roads was realized there; Second, we have formal cooperation from the administrative body of the Fukuoka RT special zone, which includes the "Robotics Industry Development Council" (RIDC) and the Fukuoka City Hall; Third, there have been many practical experiments of bipedal humanoids conducted in Fukuoka for the past decade, we have ample references and empirical data for us to investigate the legal issues of bipedal humanoids.

In this paper, our main focus is to view the impacts of the "Tokku" special zone system on human-robot co-existence society. We would like to make a systematic review for RT special zone, and further to investigate the relationship between RT special zone, robots, and the law. We will introduce the history of RT special zone for our readers in Sect. 2; address theoretical issues for RT special zone as an interface for robots and society in Sect. 3; provide a sketch of Fukuoka RT special zone and an overview of Waseda University's public road experiment in downtown Fukuoka in Sect. 4; and in Sect. 5, we will conduct a case study on legal impacts regarding bipedal humanoid robots in which the materials for the case study come from Takanishi Lab, Waseda University's experiment on WL-16RII and WABIAN-2R at the Fukuoka RT special zone.

2 The History of "Tokku" Special Zone for Robotics Empirical Testing and Development

In 2002, the Japanese government passed *The Law on Special Zones for Structural Reform*, which aims to promote socio-economic structural reform and the revitalization of the local areas through the establishment of special zones. Special regulatory measures exist in these special zones in order to stimulate the local economy [2,3]. For example, in order to overcome the *Road Traffic Act's* strict restriction on robotics research and development in laboratories, the special zones allowed preferential regulatory measures for academic institutions and private companies to test their robots on public roads.

The world's first "Special Zone for Robot Development and Practical Testing" was approved by the Cabinet Office of Japan on November 28, 2003. The RT special zone covers Fukuoka Prefecture, Fukuoka City and Kitakyushu City, where the three local public bodies jointly established the Robotic Industry Development Council (RIDC) in charge of managing and operating the whole Fukuoka RT special zone. This particular zone focused on the development of industrial, medical, welfare, secure and rescue robots. The five aims for the Fukuoka RT special zone are: (1) Building anchor points for RT startups; (2) Conducting practical testing related to RT research and developments; (3) Supporting government-industry-university collaborations that are cross-administrative; (4) Gathering robotic researchers; and (5) Developing youth scientific RT education. In addition, the RT special zone is a conceptual region legally approved by the government. If experimental regulations were successful, then the regulatory measures could be expanded into nationwide regulations or laws [4].

According to Article 3, Paragraph 3 of *The Law on Special Zones for Structural Reform*, they designed a special measure called *The Measure for Facilitating Robots' Experiment on Public Roads*. "The Measure" clearly defines robot experiments on public roads permissible by both the *Road Transport Vehicle Act* and the *Road Traffic Act* and facilitates the licensing procedures for outdoor robot experiments. Through the preferable regulatory measures, it opens a way to carry out robot experiment on public roads. The contents of the measure are as follows [5]:

1. *The Modification of To-Do-Fu-Ken Police Committee's Regulations*[1]
   According to Article 77, Paragraph 1, Number 4 of the Japanese *Road Traffic Act*, To-Do-Fu-Ken Police Committee's Regulations should be modified. The same paragraph also pointed out behaviors which need permission from the local police department, such as experiments related to robots' walking or movement on public roads.
2. *The Permission of Road Usage*
   (a) Permission for experiments in Special Zones for Structural Reform should consider the characteristics of the experiment, the capability of robots, and the traffic situation of surrounding road area. During the process of judging the application from related behaviors in Article 77, Paragraph 2, it is allowed to make the decision according to appropriate conditions.
   (b) When requesting permission for the movement of robots on the public roads, the robots of the experiment should adhere, to the best of their abilities, traffic regulations in order to prevent accidents with irrelevant vehicles or pedestrians. The experiment should be conducted under this premise, especially in conditions where the road does not have a clear sidewalk and traffic lane. Robots must obey traffic regulations for general vehicles.
   (c) Granting permission to pass through both the sidewalk and bicycle specific lane should be based the possibility of an accident; the size, weight, speed, etc. of the robot; the possible amount of damage to the human body during a collision; and a strategy from the applicant to prevent or reduce such an incident.

The Measure for Facilitating Robots' Experiment on Public Roads is a crucial initial step to realizing a society in which humans and robots coexist. The expedient regulatory measures in traffic laws reduce the institution barriers, therefore allowing robots to adapt to bumpy surfaces, surfaces with steps and pedestrians, and various locations in which outdoor conditions can be complex and unpredictable. This is important to robotists because they could ensure the robot safety through practical testing in outdoor spaces from both software and hardware perspectives. The project had initially launched in Fukuoka and Kitakyushu cities in February 2004. Takanishi Laboratory, Humanoid Robotics Institute, Waseda University had deployed two bipedal robots WL-16RII and WABIAN-2R from July 2004 to 2007. The testing was distributed among several locations in Fukuoka City: the entrance and stairway of the shopping mall *Hakata Riverain*, the zebra crossing of the *Kawabata Shopping Street*, the stairway of *Kagami Tenmangu Shrine*, *Hakata Kotobuki Bridge*, entrances of the *TNC TV Building* and *Fukuoka Tower*, and *Fukuoka Castle Ruins*. The first batch of these long-term outdoor experiments were from July 7, 2004 to December 21, 2004. This instance is known as the world's first bipedal robots' practical testing on public roads [6].

At the beginning, *The Measure for Facilitating Robots' Experiment on Public Roads* were applied in a few RT special zones between 2004 and 2006. Through extensive practical testing, the Japanese government recognized its necessity and later revised nationwide regulations in January 2006. According to the document issued on January 23, 2006 by the Traffic Bureau, National Police Agency of Japan, the special regulatory measures of *The Measure for Facilitating Robots' Experiment on Public Roads* was replaced by the following nationwide traffic regulations [7]:

1. *The Measure to Clarify the Object for Road Use Permission*: In order to overcome the barrier for experimenting robots on public roads, To-Do-Fu-Ken Police Committee's Regulations should be modified based on Article 77, Paragraph 1, Number 4 of the Japanese *Road Traffic Act*.
2. *The Basic Thinking of Road Use Permission* for the experiment for robots on public roads: the characteristics of the experiment, the capability of robots, the traffic situation of surrounding area. During the process of judging, it is allowed to make the decision according to appropriate conditions from related behaviors in Article 77, Paragraph 2.
3. *Notes for Handling the Road Use Permission* for the experiment for robots on public roads: Since the subject's safety and capability is unproven yet, the examiner will consider the necessity of traffic regulations for the experiment when deciding in order to prevent collisions with pedestrians or other vehicles.

Located in geographic center of Japan, Gifu prefecture has its own ambition to develop their RT industry. *The Measure for Facilitating Robots' Experiment on Public Roads* had implemented in Gifu's RT special zone in May 2004; its

[1] "To-Do-Fu-Ken" is an abbreviation of four kinds of first level of administrative division in Japan, they include *To* (capital), *Do* (territory), *Fu* (urban prefecture), and *Ken* (prefecture).

first outdoor testing was launched in April 2005 at *Techno Plaza* (Kakamigahara City).[2] In addition, the establishment of *Wabot-House Laboratory*[3] under the collaboration with Waseda University was also part of the Gifu RT special zone. There are three kinds of wabot-house in this project, the first one is a typical house occupied by humans, the second is designed for robots only, and the third is a special living space designed for human and robot coexistence. Researchers believe that this project may result in inventing a new social system and principle of technical designs through close interactions between human and robots at wabot houses [8].

Since 2002 the Osaka Prefecture has also started to pay attention to service robotics. It founded the "Robotic Industry Promotion Organization" (soon renamed as "Next Generation RT Industry Creation and Research Organization") in the same year. The next year it made policy guidelines that included two stages to construct its regional RT industry. The first stage aims for attracting talents and to make Osaka become a research and development center of RT, and the second stage aims to combine local resources to develop RT startups. The core idea of the guideline is "Field Creation", which has two folds of meaning. It allows a field for researchers to exchange their ideas and a field for empirical human and robot interaction testing.

Adjacent to Osaka, Kyoto and Nara Prefectures, "Kansai Science City" is recognized as Kansai area's first RT special zone in 2003, but *The Measure for Facilitating Robots' Experiment on Public Roads* had only been added to the Osaka special zone until 2005. In November 2005, when Nara Advanced Institute of Science and Technology (NAIST) started to test an electric personal assistive mobility device—Segway and a tele-operated electric wheelchair on public roads in the special zone, they found that radio transceiver may be obscured because of architectural barriers [9]. *Knowledge Capital*, an area facing the north side of JR Osaka Station, has a *RoboCity CoRE* (Center of RT Experiments) project which aims to develop and study a huge "Robo City" supporting human-robot coexistence [10].

The political power of Japan was transferred from the Liberal Democratic Party to the Democratic Party in 2009. Based on Hatoyama cabinet's "New Growth Strategy", the Japanese government created new special zone system called *The Comprehensive Special Zone*, and the policy was realized 2 years later by Kan cabinet when *The Comprehensive Special Zone Act* was enacted in August 2011.

In the same year, Tsukuba was designated *The Comprehensive Special Zone for International Competitiveness Development*—which aims for strategic development on "cancer treatment", "personal care robots", "algal biomass energy", and "TIA-nano" [11]. Its two main objectives included the study of manned/personal mobility robots on their social effectiveness, affinity to pedestrians, safety to passengers in the real world and to investigate their potential service business model.[4]

The major difference between *Special Zone for Structural Reform* and *Comprehensive Special Zone* is that the former focuses on experimental regulations for socio-economic revitalization and the latter includes special regulatory measures and considers revitalizing areas through preferential treatment like taxation and financial support. In other words, it seeks to provide comprehensive support for strategic projects in the regions [12].

Although Tsukuba City was designated as the comprehensive RT special zone, prior to its official establishment, there were two crucial projects related to human-robot coexistence underway: "Real World Robot Challenge" and "NEDO Life Supporting RT Safety Certification Center". In Japan, robots practical testing on public roads/areas has been realized nationwide since January 2006 under the prior censorship by local police departments. Based on this premise, professor Shinichi Yuta from the University of Tsukuba had launched the "Real World Robot Challenge" (a.k.a. "Tsukuba Challenge") in 2007, and it aims for enhancing autonomous mobile robots' capability to perform their tasks in real world unstructured environments. By estimation, there were 280 teams that participated in the challenge in Tsukuba City from 2007 to 2011 [13]. New Energy and Industrial Technology Development Organization (NEDO) had funded a 5 year project for the establishment of Life Supporting RT Safety Certification Center in Tsukuba 2010. Its objectives are "to seek risk assessment approaches for life supporting robots" and to develop life supporting robots embedded with safety measures [14].

Compared to other RT special zones, the latest Tsukuba RT special zone is not only approved as part of the *Comprehensive Special Zone*, but it is also the first special zone that applied *The Measure for Manned Mobility Robots' Empirical Experiment on Public Roads*. Compared with the previous *The Measure for Facilitating Robots' Experiment on Public Roads*, it suggests special measures for road usage permission and regulatory measures related to road traffic be added, as following:

– *"Road Traffic Act"*:
  1. Vehicles with Special Structure be Appointed by Prime Minister.
  2. The Measures for Asking Powered-Bicycle Should Show a Sign on its Back.
  3. Relevant Measures to Road Usage Permission.

[2] http://www.vrtc.co.jp/gift/tokku/tokku.html.

[3] http://www.wabot-house.waseda.ac.jp.

[4] http://www.rt-tsukuba.jp/policy.

– *"Road Transport Vehicle Act"*:

1. Vehicles with Special Structure be Appointed by Traffic Minister.
2. Safety and Security Standard for Road Transport Vehicle.
3. Relevant Special Measures to Accept the Signing Responsibility of Alleviating Judgment of Standard for Road Transport Vehicle.
4. Principles for Judging Standard Alleviating Vehicles.

On December 27, 2012, the National Police Agency created new special traffic measures for manned mobility robots. For example, the RT public road testing can be exempted from erecting boundary signs if the highest speed of manned mobility robots is lower than 10km/h [15]. There was progress of highway experiments in the RT special zone in addition to street experiments. In 2013, Nissan carried out Japan's first public road test of a LEAF autonomous vehicle from Samukawa-South IC to Samukawa-North IC of the Metropolitan Inter-City (KEN-O) Expressway [16].

In the past decade, Japan had invested a huge amount of resources to support robots outdoor empirical testing and the outcome has been fruitful. The RT special zone is a milestone which served as a platform to coordinate technical and social systems in regard to robotics.

3 "Tokku" Special Zone as an Interface for Robots and Society

According to the prediction from the Japanese Ministry of Economy, Trade and Industry (METI), the "Human-Robot Co-Existence Society" will be fully developed between 2020 and 2030. At present, it is just in its infancy, and there will be more and more robots entering human living spaces within the next decade [17]. Thus, it is understandable that the conflicts between advanced robotics and current existing laws will occur more frequently in the future. This will lead to a potential crisis for balancing industrial competitiveness and legal openness.

3.1 Short-term Focus: A Policy Making Tool via "Deregulation"

Yoichi Takamoto who is the CEO of Tmsuk, one of the representative Japanese RT companies that specializes in service robots. He said that

> *the Japanese are conservative, they are shy to trying new emerging technologies such as service robots. Besides, they would like to set a bunch of strict laws to prevent any unwanted risks caused by next-generation robots. The average administrative approval is about more than 1 year, which is twice of the time span of industrial robots* [18]

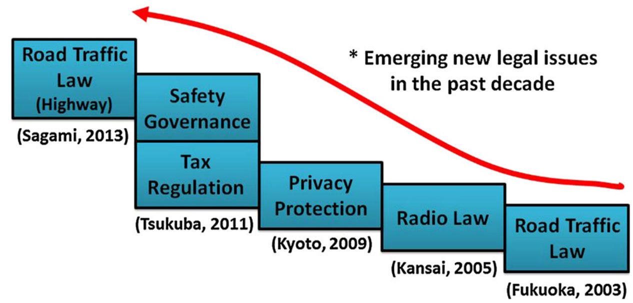

Fig. 1 A trend of rising legal issues from RT special zones

Such "Cautious Attitude" hurts Japanese competitiveness in the service robotics industry. From the short-term perspective, the importance of RT special zone is through "deregulation" [19] to cover many potential legal disputes derived from next-generation robots when they are deployed in the real world. Japanese official believes a special zone for deregulation can finally ease the overregulated legal barriers and enhance its RT industrial competitiveness.

We collected data from several RT special zones on a national scale, and found a trend of rising legal issues with service robots in the unstructured environments in the past decade (Fig. 1). The first legal issue around next-generation robots came from RT special zone in 2003. Road traffic laws for bipedal walking robots were not designed yet, therefore the police department could not allow the Takanishi Laboratory to test our WL-16RII bipedal walking robots on public roads. It was not until the next year that *The Measure for Facilitating Robots' Experiment on Public Roads* framework was created under the RT special zone. The street experiments for next-generation robots was then only allowed within the special zone. However, in this section we only focus on legal issues which evolved in RT special zone in the past decade. As for details regarding the street experiment in Fukuoka RT special zone and our case study on legal impacts to humanoid robots, they will be discussed later in Chapter 4 and 5 respectively.

With the exception of bipedal walking robots, self-balancing personal transporter "Segway" was not allowed on public roads due to safety considerations. In April 2004, Tokyo Summary Court fined Segway's local distributor 500,000 yen for violating the *Road Traffic Act* without a valid motor vehicle inspection certificate and compulsory automobile liability insurance policy. The result was that the applications of Segway were limited in private facilities, such as factories and shopping malls [20]. While Segway were banned on public roads by the *Road Traffic Act*, the RT special zone opens another possibility towards its usage in daily living spaces.

In November 2005, a Segway and a tele-operated wheel chair were approved to be tested on public roads by *The Measure for Facilitating Robots Experiment on Public Roads* in Kansai Science City. This experiment not only eased the awkward situation of Segway in Japan, but also publicized the legal issue on radio law and tele-regulation. When exempted from the restriction of special certification for experiments using the 5GHz wireless frequency range, experts found that radio transceiver may be obscured because of architectural barriers.

Supported by Japanese Ministry of Internal Affairs and Communication (MIC), Kyoto's ATR Intelligent Robotics and Communication Laboratories launched the *UNR - Ubiquitous Network Robots Research Project* in 2009. The main purpose is to create core technologies and common platforms allowing network robots to provide services of human-robot interaction [21]. Part of the project was conducting a field experiment in a real supermarket of Kyoto, researchers used a humanoid robot to carry a shopping basket for elderly people [22]. This experiment not only showed an ethical issue that the difference of human-robot interaction between a "Tool" and a "Partner" metaphor [23], but it also accompanies a legal issue as privacy protection. ATR's Norihiro Hagita pointed out a challenge for network robots will be how to smoothly collect personal data and properly solve those potential disputes regarding privacy [24].

Lacking robot inspection certificate is a popular problem for service robots at this time. In February 2014 ISO international organization for standardization published the new ISO 13482 as the world's first safety standard for personal care robots. This will also bring structural and influential impact for next generation robots' safety certification, product liability, ethics and insurance in the future [25]. In the mean time, we might call these regulatory issues *"Robot Safety Governance"* [26], the initial step of safety governance was realized at the NEDO Life Supporting RT Safety Certification Center of the Tsukuba RT special zone. Another legal issue from Tsukuba is tax regulation, each RT related enterprise who participates public road experiment have to attach a "Robot Number" plate on its robots as a tax license.[5]

The implementation of coordinating technical and social systems for advanced robotics in the real world is rare outside of Japan. However, there is an experiment known as *"Peccioli RoboTown"* in Italy. As part of the European DustBot project [27], the experiment deploys two autonomous mobile robots called *DustCart* to collect domestic wastes in the street of Peccioli, a small historical town in Tuscany. The duration of the project was from June 15, 2010 to August 7, 2010. The robots collected the waste from the participants which including 24 families and 10 business shops of Peccioli. By estimation, the total service time was 454 h, and the services provided were 402 times, the total distance that robots travelled were 120.6 km, and the total weight of garbage that robots collected was 584.1 kg.[6]

However, an *"autonomous vehicle"* is a contradiction with the road traffic convention and the Italian highway code. Through the collaboration with the local police, the experiment is allowed by special expedient measures to "design new road signs", "set up dedicated *robot lane*", "negotiate a new insurance policy for robots", and "erect test site warnings to avoid privacy concerns" [28].

In Japan, settling a rational insurance policy for service robots which participating in the public road experiment has always been an open question since the establishment of Fukuoka RT special zone. As for the Peccioli experiment, the insurance company requested a 850 euro additional insurance fee, and the robots were insured against any liability resulting from their research activities in the town [29].

Google's self-driving cars faced similar difficulties in legal and insurance restrictions in the United States. Up until now, only California, Nevada and Florida have approved the test of self-driving cars to access on public roads. Nevada is the first American state to pass regulations allowing for the operation of self-driving cars. State traffic laws requires self-driving cars be distinguished as "Autonomous Test Vehicles" with red license plates displayed on the public roads [30].

Although Google's self-driving car has passed 300,000 miles testing in California alone without any serious trouble [31]. Japanese RT special zone's special measure for experiment on public roads is more cautious from a safety governance perspective. In the very least, it can effectively control damage range caused by *Type I* (False-Positive) or *Type II* (False-Negative) errors from self-driving cars to improve security for inhabitants and their properties of the city [32]. In June 2014, the University of Michigan had announced the building of a "Faux Downtown" outside Ann Arbor, something similar to the "Tokku" special zone for testing the city-driving worthiness of a self-driving car without subjecting a city to the risks [33].

Recently, the Cabinet of Japan established the *Robot Revolution Realization Council* in order to making comprehensive policy guidelines for the country's future strategic development of RT industry. Japanese Prime Minister Shinzo Abe held the first meeting of the new council on September 11 2014. Although policy guidelines are still being drafted, as far as we know deregulation is one of several core issues on the council's conference table. Without deregulation, the current overruled Japanese legal system will be a major obstacle to the realization of its RT business competitiveness [34] as well as the new safety for human-robot co-existence [35].

[5] http://council.rt-tsukuba.jp/info/2011/04/08/133.

[6] http://www.robotown.eu.

Up until now, the Japanese Robot Revolution Realization Council had systematically inspected potential problems from its legal system, and they concluded many overruled existing regulations as follows: "Radio Law", "Pharmaceuticals and Medical Devices Law", "Industrial Safety and Health Act", "Road Traffic Law", "Road Transport Vehicle Act", "Civil Aeronautics Act", "Control Law of Injustice Access", "Consumer Products Safety Act", "ISO 13482 Safety Standard for Life-supporting Robots", "Industrial Standards Law" [36].

As mentioned above, the importance of RT special zone in the short-term is through "deregulation" to cover current disputes by next-generation robot in its infancy.

3.2 Long-term Impacts: An Interface for Robots and Society or "Shock Buffer"

On the other hand, in the long-term, RT special zone is an interface between robots and society or a "shock buffer" for supporting human-robot coexistence. Its major functions are as follows:

(1) *"To Ensure Machine Safety"*:

ISO 12100's "3-Step" method for risk reduction are "inherently safe design measures", "safeguarding and complementary protective measures", and "information for use" [37]. Due to the open-texture risks in unstructured environments, the machine safety of service robots will not the same as current industrial robots. For example, while the effectiveness of inherently safe design measures become less important, measures for safeguarding, complementary protection, and informational use become more important. However, safeguarding and complementary protective measures, especially functional safety and information for use, will need a semi-open region such as RT special zone. This zone will provide developing robots various empirical testing opportunities to simulate situations of human-robot coexistence.

In addition, the rates of "Modeling Error" increase in unstructured environments, and RT special zones can prevent these errors by conducting the same type of empirical testing several times.

Finally, RT special zone has one more measure to ensure safety: "Robotics Nurburgring". As one of the most rigorous in the world, the Nurburgring motorsports complex was founded in the 1920s in western Germany. This site allows many major automobile makers to test the reliability and safety of their new cars before releasing them into the market. Unlike University of Michigan's "Faux Downtown", which focuses on the scenario-oriented back-end testing. We believe that the "Robotics Nurburgring" could be a similar entity for robotics makers to conduct front-end empirical testing of new products.

(2) *"To Prevent High Litigation Risk"*:

The other benefit of the RT special zone is that it could be a "Protective Shield" for robotics companies to prevent high litigation risk during the developmental stages. Although no machine can be 100 percent perfectly safe, international safety standards such as ISO and IEC certifications can regulate manufacturers' products. If the manufacturers can prove their products are safe, then perhaps they can be exempt from product liabilities. However, the safety of human-robot coexistence is different to traditional safety of industrial robots because of "unstructured environments". Unstructured environments is complex as it may include people, objects and architectures within it. Therefore, adopting RT special zone to support the development of robot can avoid high risks of product liability litigation for robotics makers.

(3) *"To Ease Radical Ethics Disputes"*:

The reason we adopt humanoid robots is very simple: its shape fits human living spaces, and thus people naturally know how to interact with them. However, the moral and ethical risks from humanoids are an unavoidable problem. GeorgiaTech's Prof. Henrik I. Christensen predicted that

> *We are getting into the issue of how you want to interact with these robots... Should you be nice to a person and rude to their likeness? Is it okay to kick a robot dog but tell your kids to not do that with a normal dog? How do you tell your children about the difference?* [38]

Up until now, there are no legal norms which define the proper relationship between human users and the "Third Existence" sociable robots which have both "tool" and "partner" metaphors. A critical scenario among these issues is whether to prohibit advanced robotics to be applied into human-like rubber dolls for normal commercial applications. For example, David Levy claimed that he believes robot will finally become humans' faithful sexual companion as love and sex with robots will be a trend in the future [39]. Currently in Japan, there are several sex toys makers who are studying trends of applying advanced robotics into human-like rubber dolls. It is expected that the human-like rubber dolls will be equipped with intelligent functions which enable the dolls to naturally interact with humans in a vivid way.

As such, there may be moral risks if such products are not regulated; we can not ensure which kinds of negative impacts it could bring to the society. Therefore, we should consider observing and establishing an "Isolated Region" for emerging robotics that face strong ethical issues but currently do not

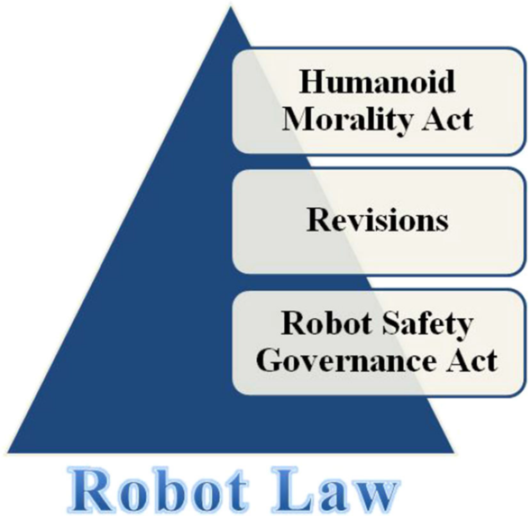

Fig. 2 The three-level hierarchy of "Robot Law"

fall under any types of legal jurisdictions. Such observations may help law makers to address any ethical issues and create regulations for robots. Another example is that an Italian robotics group conducted an empirical outdoor observation on robot social acceptability during a demonstration in a public square. During the observation, they found that young people tend to react to the robots' presence with extreme curiosity and, quite often, when the robots were left unsupervised, to treat them aggressively [40]. If so, RT special zone will be a practical region for conducting similar empirical observations.

RT special zone is a "Double-edged sword" and it also has a dark side that most people might overlook. Regulators and lawmakers should be very cautious in its design and applications. Though "Tokku" itself is a regulatory tool for easing radical ethics disputes, we worry that it might be misused which will result in unwanted human-robot relationships. Take the upcoming sci-fi film "VICE" as an example: a businessman has designed a law-free resort: "VICE" another RT special zone where the customers can play out their wildest and unethical desires with any robots who look, think and feel like humans [41].

3.3 On the Structure of "Robot Law"

Finally, through the above analysis and empirical data collected from the Fukuoka Tokku, we found the structure of emerging "Robot Law", which could be divided into three different categories (Fig. 2):

1. *"The Robot Safety Governance Act"* is the extension of current machine safety regulations. An example of a current regulation is EU Directive or UNECE's motor vehicle "Type Approval", these regulations are used to represent in a highly technical way, or called *"Technical Norms"*. *The Robot Safety Governance Act* located at the bottom of *"Robot Law"* will ensure the safety of new human-robot co-existence. Because ISO and IEC safety standards lack enforceability, sometimes we may need *The Robot Safety Governance Act* to supervise the robotics makers follow a global consensus when manufacturing reliable and safe robots for people. Plus, unknown new risks of service robots and the complexity of their adaptiveness with human living spaces will force us to seek a regulatory framework in order to concord with the new safety measures of human-robot co-existence. Therefore, new laws that will be needed may be similar to the risk regulatory framework for the production of genetic food or new drugs. Compared to current safety governance regulations for industrial robots, electric elevators, vehicles, railway systems, we found a demand for new the *Robot Safety Governance Act* to address ethical impacts of third existence autonomous robots, such as the theoretical framework *"Safety Intelligence"* we proposed earlier [42].
Patrick Lin argues autonomous self-driving cars will need embedded ethical codes to help these cars make correct decisions in real-time [43] around humans and on public roads, which is crucial to the safety governance of self-driving cars. As for humanoid robots, in the future they will not only perform daily duties outside but also able to enter inner spaces of buildings in urban area. With this, highly autonomous humanoid robots will have larger scale of demands of programmed ethical codes than autonomous self-driving cars.
There will be two main challenges for integrating the code of ethics into robot safety regulatory framework. From technical perspective, we have to consider how to provide a feasible framework embedded ethics into robots without Asimov's Three Laws of Robotics [44], such as the *Ethical Governor*, proposed by GeorgiaTech's Ron Arkin [45].
On the other hand, another challenge to realizing programmed code of ethics depends on attitudes from the lawmakers and regulators to the emerging "Ethics by Design" principle. Under the safety intelligence framework, we have a proposal for an alternative *"Legal Machine Language"* based on two principles: Code is Law and Embedded Ethics. However, if the "Code" is not able to be authorized with legal effectiveness, then it is merely a set of machine languages. It would be similar to today's "technology protection measurements" - using code to limit human's illegal behaviors of copying, but the code themselves are not real law. Another example is "Privacy by Design": specific code inside information systems are used as a technological measure to protect privacy.

In the future or in the middle stage of human-robot co-existence society, it is inevitable to consider a safety abiding "Ethics by Design" principle to embedded code for limiting autonomous robots' behavioral risks. However, to highly autonomous robots who perform like human beings, it is not ethical to entrust robot manufacturers to apply the "Ethics by Design" principle under a policy in which the code of ethics is as a responsibility associated with the job as this not enough to ensure safety. In such scenarios, robot manufacturers have to take consumers' preference as a priority, otherwise they may lose the market share from their competitors. In the worst situation, the safety-oriented ethical codes may lose their original purpose when too many commercial interests seep into its designing stage. Furthermore, it is seriously against Immanuel Kant's ideals that "humans should not mistreat the entity in question, even though it lacked rights itself", when highly autonomous robots' behaviors are constrained by human's commercial interests [46].
Above all, our proposal of a "Code is Law" is that the code of ethics should not simply be one of the manufacturers' self-responsibility, but it should further become a part of statute law or "Technical Norms". Although this enables the code of ethics to be well supervised during its designing stage, a major problem still falls on how to authorize the code of ethics with legal effectiveness as it relates to keeping a balance between many conflicts of interests.
2. *"The Humanoid Morality Act"*: Osaka University's Hiroshi Ishiguro predicted that with humanoid robot's intelligentization, we will face the problem on how to decide "Robo-rights" when robots became inseparable entities of human society. He also pointed out that current legal system uses "flesh" as an index for judging humans, animals or objects' status and right. However, when the boundary of flesh and machines get closer, it will bring serious impacts to human legal system [47].
One possibility to solve above problem is to consider the *"The Humanoid Morality Act"*, which should be at the beginning of *"Robot Law"*, will define a proper relationship between human and robots, and using coercive power to constraint unethical applications of humanoid robotics or cyborg technologies. It will construct a fundamental norm for regulating daily interactions between human and robots. However, its importance will increase as the development of robotics applications in human society expand.
3. *"Revisions"* will refer to the current existing laws that need to be revised due to conflicts with advanced robotics. It is strongly connected with the issue of deregulation, areas may include privacy protection laws, road traffic acts, international humanitarian laws, tort laws, etc...

4 Introduction to Waseda University's Public Road Experiments in Fukuoka RT Special Zone

The US Defense Advanced Research Projects Agency (DARPA) hosted the *DRC-DARPA Robotic Challenge* in December 2013.[7] The contest asked participating humanoid robots to accomplish many complex missions, including driving a vehicle, moving through obstacles, walking through difficult terrain, opening gates, climbing ladders, breaking concrete walls using tools, closing valves and connecting a fire hydrant. Team "SCHAFT" accomplished all challenges and got the highest score of 27 points to be the champion of 2013 DARPA Robotic Challenge. This contest showed humanoids' high adaptability in human living environments and the technical maturity of bipedal dynamic walking mechanism.

The research and development for humanoid's bipedal walking actually has 40 years of history since the world's first humanoid "WABOT-1" had been invented in 1973. Here we believe that humanoids entering the human society to serve people in their daily lives will be a promising future. Thus, we have conducted a case study on legal impacts to humanoids, and the materials of this study came from our early public road experiments in Fukuoka RT special zone during 2004–2007.

4.1 A Sketch of Fukuoka RT Special Zone

Since the establishment of the Fukuoka RT special zone in 2003, there were 22 road use permissions issued by the local police department. The applicants includes "Takanishi Laboratory, Waseda University", "Fujie Laboratory, Waseda University", "Hasegawa Laboratory, Kyushu University", "tmsuk Co. Ltd.", "Institute of Systems, Information Technologies and Nanotechnologies (ISIT)" etc...[8]

According to a joint proposal published by Fukuoka City, Kitakyushu City and Fukuoka Prefecture in 2003, there were eight objectives for the special zone to achieve 10 years later, they are:

1. The creation and new entry of the robot-related companies: "100 companies"
2. The amount of increase to RT product shipments: "450 billion yen"
3. Job Creation: "1,900 positions"
4. Conducted empirical experiments: "250 times"
5. Robot products commercialization from empirical experiments: "50 robots"
6. Academic paper publication and citation: "100 papers/citations"

7 http://www.theroboticschallenge.org.

8 The data come from non-disclosed documents of Fukuoka City Hall.

Eight Objectives for the Fukuoka "Tokku"	Criteria (2003)	Realization (2013)	Achievement Rate
(1) Companies and Value Creation	100 companies	34 companies	34%
(2) The Amount of Increase to RT Product Shipments	450 billion yen	10.757 billion yen	2.39%
(3) Job Creation	1,900 jobs	- 4,153 jobs	- 218.57%
(4) Conducted Experiments	250	108	43.2%
(5) Robot Product Commercialization	50 robots	30 robots	60%
(6) Academic Publication	100	n/a	n/a
(7) Patent Application	50	n/a	n/a
(8) Enterprises in the Town	10	n/a	n/a

Fig. 3 A sketch of Fukuoka RT special zone

7. Patent application which relate to the process of empirical experiments: "50 applications"
8. Enterprises and academic institutions in the town: "10 institutions"

Based on the statistical data provided by the Roboti-cs Industry Development Council,[9] we made the following table as a sketch of Fukuoka RT special zone (Fig. 3).

4.2 The Fukuoka Experiment (2004–2007)

The empirical experiment had initially launched in Fukuoka and Kitakyushu cities in February 2004: Takanishi Laboratory, Humanoid Robotics Institute, Waseda University had deployed two bipedal humanoid robots WL-16RII and WABIAN-2R from 2004 to 2007 (Fig. 4). The testing was distributed among several locations in Fukuoka City: the entrance and stairway of the shopping mall *Hakata Riverain* (Shimokawabata, Hakata-ku), the zebra crossing of the *Kawabata Shopping Street* (Kamikawabata, Hakata-ku), the stairway of *Kagami Tenmangu Shrine* (Shimokawabata, Hakata-ku), *Hakata Kotobuki Bridge* (Shimokawabata, Hakata-ku), the entrances of the *TNC TV Building* and *Fukuoka Tower* (Momochihama, Sawara-ku), and *Fukuoka Castle Ruins* (Shirouchi, Chuo-ku). The first batch of these long-term outdoor experiments were from July 7, 2004 to December 21, 2004. This instance is known as the world's first bipedal humanoid robots practical testing on public roads.

4.3 Bipedal Humanoid Robot WABIAN-2R

WABIAN-2R (WAseda BIpedal humANoid—No. 2 Refined) was developed in order to investigate a cooperative dynamic walking and a collaborative work with humans. It is a


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福岡市のポテンシャルと課題等の調査研究

に関する報告

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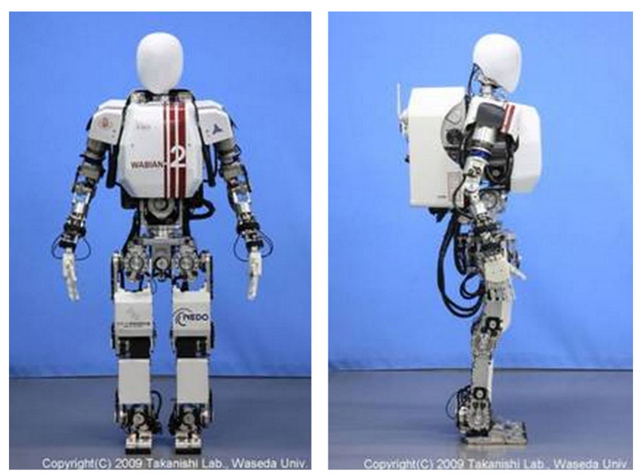
修士 1 年 川瀬正幹、橋本健二
理工学部 学部 4 年 太田章博、田中智明

Fig. 4 The Fukuoka report for Robots' development and practical testing in RT special zone (2005)



Front　Right

Fig. 5 WABIAN-2R (WAseda BIpedal humANoid—No. 2 Refined)

humanoid robot with the height of 1500 [mm], and the weight of 60 [kg] (Fig. 5). In order to mimic human movements, the robot has 41 DOFs and the movable range of the joints designed in reference to human anatomy. The computer mounted on the trunk controls the motion of WABIAN-2R. It consists of a PCI CPU board and PCI I/O boards. As the I/O boards, HRP interface boards (16ch D/As, 16ch counters, 16ch PIOs) and 6-axis force/torque sensor receiver board are mounted. The operating system is QNX Neutrino ver.

[9] The data come from non-disclosed documents of Robotics Industry Development Council (RIDC).

Height [mm]	1500
Weight [kg]	64 (with batteries)
Degrees Of Freedom (DOF)	Leg: 6 x 2 Foot: 1 x 2 (passive) Waist: 2 Trunk: 2 Arm: 7 x 2 Hand: 3 x 2 Neck: 3 Total: 41
Sensors	6 Axis Force / Torque Sensor Photo Sensor Magnetic Encoder Gyro Sensor
Actuators	DC Servo Motor
Reduction Mechanism	Harmonic Drive Gear Timing-belt/pulley
Batteries	Li-ion Battery

Fig. 6 The specification of WABIAN-2R

6.3. The drive system consists of a DC servo motor with an incremental encoder attached to the motor shaft, and a photo sensor to detect the basing angle. Also, each ankle has a 6-axis force/torque sensor, which is used for measuring Ground Reaction Force (GRF) (Fig. 6).

Two purposes of WABIAN-2R are (1) to develop a robot that would be a human's partner, and (2) to develop a human motion simulator. In order to realize the goal of the former, it is indispensable to release WABIAN-2R from the laboratory into the public area. However, in addition to safety and reliability issues, legal issues are also critical challenges for bipedal walking humanoid robots to enter the human living spaces.

4.4 WABIAN-2R and the experiment in TNC-TV building

An experiment was conducted in 2007 to apply a landing pattern modification method adaptable to uneven terrain in a real environment based on a predictive attitude compensation control and a nonlinear compliance control equipped with WABIAN-2R. The testing site was in the outdoor surface around the *TNC-TV Building* (2-3-2, Momochihama-machi, Sawara-ku, Fukuoka-shi, Fukuoka, Japan, 814-0001), and the aim of the experiment was to verify WABIAN-2R's adaptiveness in outdoor environments such as pedestrian and gravel roads [48].

The experiment was conducted as follows (Fig. 7):

1. On a bumpy surface with uneven tiles angled 2° (left-right-axis).

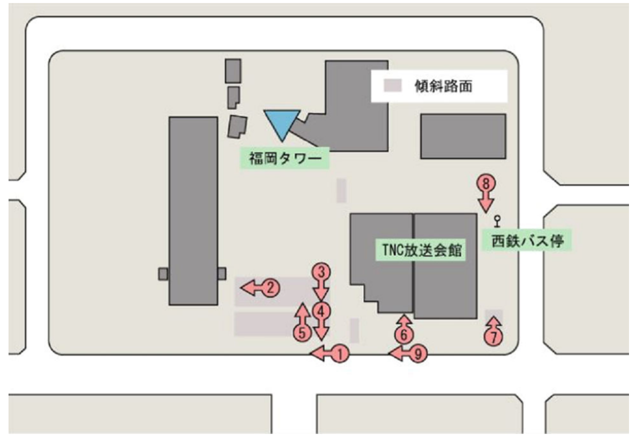


Fig. 7 WABIAN-2R's experimental site: Fukuoka TNC-TV building

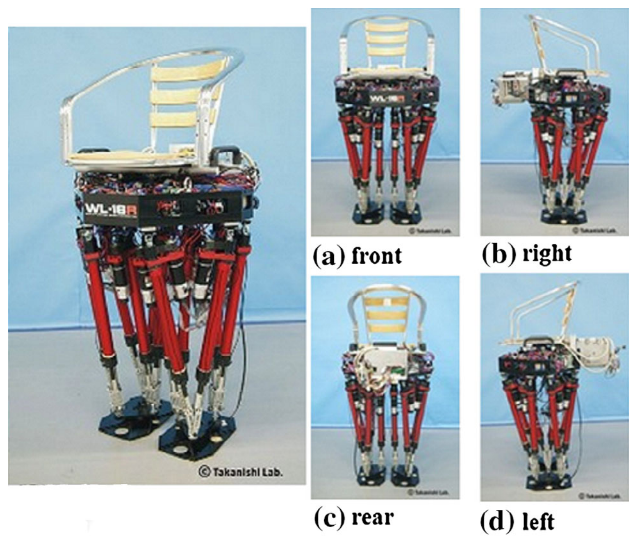


Fig. 8 WL-16 RII (Waseda Leg No.16 Refined II)

2. On a smooth surface with tiles angled 3° (left-right-axis).
3. On a smooth surface with tiles angled 3° (forward-axis) down.
4. On a smooth surface with tiles angled 5° (forward-axis) down.
5. On a smooth surface with tiles angled 5° (forward-axis) up.
6. On a bumpy surface.
7. On a bumpy surface with tiles angled 2°−5° (forward-axis) down.
8. On a smooth surface with tiles.
9. The same as 8.

4.5 Multi-purpose Bipedal Locomotor WL-16RII

WL-16RII (Waseda Leg—No.16 Refined II) is a bipedal robot with only lower-limbs and a waist that can walk independently (Fig. 8). Its upper body can be developed by users

Height [mm]	1160-1500
Weight [kg]	52 (with batteries)
Degrees Of Freedom (DOF)	6 DOF x 2 = 12
Link Mechanism	Stewart Platform
Sensors	Force / Torque Sensor x 2
	3 Axis Angle Detector x 1
	Rotary Encoders x 12
	Photomicrosensor x 12
Actuators	DC Servo Motor x 12
Batteries	Nickel Metal Hydride Battery
Others	Electromagnetic Brake x 12
	Wireless LAN Module
Loading Capacity [kg]	Normal: 0-60
	Using STRM: 0-94

Fig. 9 The specification of WL-16RII

Fig. 10 WL-16RII's experimental site: downtown Fukuoka

according to their purposes. This biped locomotor would be applicable to the welfare field as a walking wheelchair or as a walking support machine that is able to walk up and down stairs carrying or assisting a human. In addition, in order to accomplish a high independence in outdoor environment, its power is driven by a battery, and 6-DOF parallel mechanisms had adopted. WL-16RII's gross weight is 52 kg including a 7 kg battery, and its height about 1.2 m (Fig. 9).

4.6 WL-16RII and the Experiment in Downtown Fukuoka

See Fig. 10, the testing spots were distributed in several corners of Fukuoka City the entrance and stairway of the shopping mall *Hakata Riverain* (A-Spot and B-Spot; 3-1, Shimokawabata, Hakata-ku, Fukuoka city, Fukuoka, Japan, 812-0027), the zebra crossing and pathway of the *Kawabata Shopping Street* (C-Spot and D-Spot; 6-135, Kamikawabata, Hakata-ku, Fukuoka city, Fukuoka, Ja-pan, 812-0026), the stairway of *Kagami Tenmangu Shr-ine* (E-Spot; 3-1, Shimokawabata, Hak-ata-ku, Fukuoka city, Fuk-uoka, Japan, 812-0027), and *Hakata Kotobuki Bridge* (F-Spot; 3-1, Shimokawabata, Hakata-ku, Fukuoka city, Fukuoka, Japan, 812-0027). The first batch of these long-term outdoor experiments was from July 7th, 2004 to December 21st, 2004 and they are known as the world's first bipedal robots practical testing on public roads.

5 Case Study: Legal Impacts to Bipedal Humanoid Robots

The authors conducted a patent research from the Japanese Patent Office's (JPO) IPDL database. Under the F-term *3C007* technical theme *"Manipulator-Robot"*, we chose three technical tags: *LW11 "Artificial Intelligence"*, *MS27 "The Safety for Human"* and *WA13 "Bipedal"*. We found that there are 135 patents from 1985 to 1990, 157 patents from 1991 to 1995 (Honda holds 57 patents among them), and 144 patents from 1996 to 2000 (Honda and Sony holds 30 and 15 patents respectively), 689 patents from 2001 to 2005 (Sony, Honda, Toyota and Kawada holds 220, 126, 31 and 24 patents respectively), and 683 patents from 2006 to 2013 (Honda, Toyota, and Sony holds 174, 146 and 55 patents respectively).

The results could reflect a long-term trend of practical development for bipedal walking humanoids. However, humanoids entering the society need both technical and social attention: law, ethics, and policy are indispensable. From the public road experiment in Fukuoka RT special zone, we found legal issues which are related to the real implication of bipedal humanoid robots:

(1) *"Robots and Road Traffic Acts"*

The problem for bipedal walking robot on public road is related with road traffic laws, that the regulation of the autonomous robot is not designed on any Japanese law. Therefore, local police department could not allow us to make our humanoid robots walk on public roads. But under the RT special zone framework, the Fukuoka City government is able to help us acquire the road use permission.

Comparing to Europe, Japan has a clear procedure for using robots on public roads, such as the previous *Measure for Facilitating Robots' Experiment on Public Roads* and the new *Measure for Manned Mobility Robots' Empirical Experiment on Public Roads*.

Paragraph 1, Article 77 of the Japanese *Road Traffic Act* authorized special measures of *The Measure for Facilitating Robots' Experiment on Public Roads*, enabling robots to formally be allowed for use on the road. However, the submission of the application should correspond to conditions listed on Paragraph 2, Article 77 of the *Road Traffic Act*, in addition to receiving permission from local police department. In other words, in *Road Traffic Act*, the regulations for robots are different from the conventional regulation for vehicles, which is an expedient measure but not recurring way of road use regulation. On the other hand, up until 2012 in the United States, there had been three states that already made special measures for Google's unmanned vehicle on the road: Nevada, Florida and California. However, there are several distinct differences between RT special zone and the special measures for Google's unmanned vehicle. For example, the type of robots under the RT special zone are not limited to wheel-triggered robots or robotized vehicles. In fact, it allows various types of robotics locomotion, such as bipedal locomotion. In addition, the activities are not limited to roads but may also include shopping malls, hotels, shrines, TV stations, etc. In brief, the RT special zone is more relevant to regions of human activity. Therefore, the dimensions are more complex than traffic regulations on public roads.

(2) *"Robot Safety and Product Liability"*

If manufacturers can prove that their products are safe and not defective, then they can be exempt from product liabilities. A crucial one factor is whether they can produce robots according to internationally recognized safety standards such as ISO or IEC's or not. Unlike current existing industrial robots' safety standards, the new *ISO 13482 Safety Standard for Personal Care Robots* will be the first robot safety standard made by ISO international organization for standardization. This allows robots and humans to touch each other, share the same space and provide services to humans. The new ISO 13482 safety standard includes (1) *Mobile Servant Robots*, (2) *Person Carrier Robots*, and (3) *Physical Assistant Robots* as the three main categories of safety requirements. Thus, the "new Safety for Human-Robot Co-Existence" could be realized based on the 13482 standard. However, the new ISO 13482 standard does not cover specific safety requirements for bipedal walking humanoids, and an option may be to develop safety strategies for humanoids' potential risks of falling down for service robots in the future. Fortunately, both Waseda University and AIST have research contributions on "Functional Safety" for bipedal humanoids [49,50].

(3) *"Technical Risks for Bipedal Humanoids"*

As mentioned before, an experiment called the European DustBot project deployed an autonomous *DustCart* mobile robot to collect domestic waste in the streets of Peccioli from June 15, 2010 to August 7, 2010. They found several legal barriers from the experiment. Specifically, Article 8 of the *Vienna Convention on Road Traffic* states that *"each moving vehicle, including animals, shall have a driver."* Therefore an autonomous mobile robot contradicts the road traffic convention and the Italian highway code. From the Peccioli experiment, there are several apparent conflicts between advanced robotics and current existing laws, such as road traffic regulations, tort liability distribution, personal data protection, and criminal liability of traffic accident.

Comparing with the wheel-triggered *DustCart* robot in Peccioli experiment, the walking stability of bipedal humanoids is a big challenge, especially the technical risks it involves. At present, the applications related to higher level autonomy such as full autonomous navigation planning and reasoning are still very limited for bipedal humanoids [51], but lower level autonomy such as keeping balance for bipedal walking is relatively well developed. In addition, intelligence is also a necessary condition for applying higher level of intelligent functions for humanoids. In history, there has never been any bipedal walking artifacts appearing in environments occupied by people. Objects regulated by traffic laws only include animals, animal pulled carts, powered vehicles, motorcycles, bicycles, etc. The issue of stability for humanoids' will be a new challenge for traffic regulators.

Regarding the control mechanisms of humanoids, WABIAN-2R and WL-16RII are two bipedal robots that have adopted walking control methods based on ZMP criteria. The criteria can be divided into two main parts [52]:

1. *Walking Pattern Generation*: Before walking as the feed forward control of the biped walking system, include: "modeling of the robot", "derivation of the ZMP equations", "computation of approximate waist motion", and "computation of strict waist motion by iteratively computing the approximate waist motion".
2. *Real-time stabilization control* during walking as the feed back control. Since our walking pattern generation algorithm outputs a stable walking pattern offline beforehand, the robot becomes unstable due to the landing impact according to modeling errors. An example of a modeling error is the deflection of the surrounding structures. There is concern that this landing impact would be disastrous when the robot walks under conditions that create large deflection of structures and results in an error when walking with a heavy payload or carrying a human. Therefore, using the virtual compliance control, we planned to moderate the landing impact and stabilize walking under such conditions.

From Fukuoka empirical experiment, a major concern was the humanoids' walking stability derived from a walking pattern that was established offline in advance. Therefore, its adaptiveness to real world public roads will face the *"Open-Texture Risk"* [53] which includes interaction between unknown surfaces and human errors. The former includes uneven terrains and heavily skewed surfaces; and the latter refers to actively keeping balance

Fig. 11 WABIAN-2R walked on the bumpy surface with tiles angled $2^{\circ}-5^{\circ}$ (forward-axis) down (experimental site no. 7)

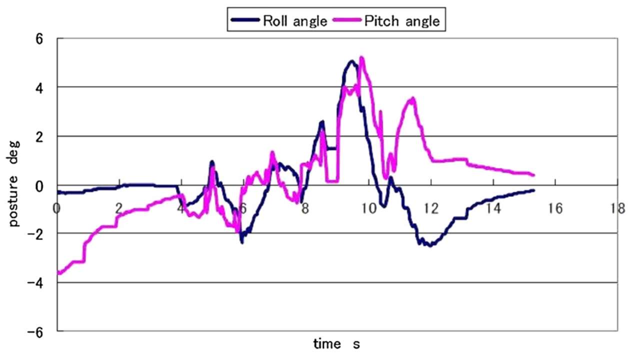


Fig. 12 WABIAN-2R walked on the bumpy surface with tiles angled $2^{\circ}-5^{\circ}$ (forward-axis) down (experimental site no. 7)

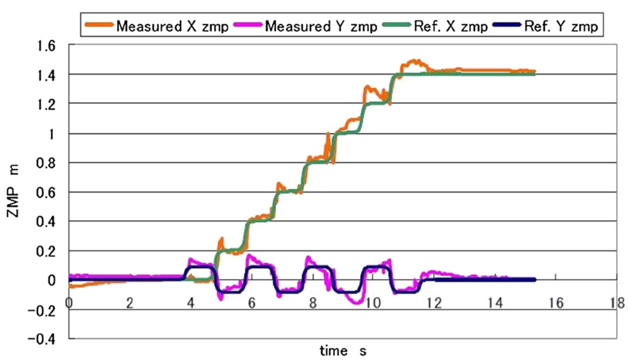


Fig. 13 WABIAN-2R walked on the bumpy surface with tiles angled $2^{\circ}-5^{\circ}$ (forward-axis) down (experimental site no. 7)

while suffering force disturbances from people in outdoor environments.

From the aspect of open-texture risk, the physical injuries and damages created by autonomous robots could be seen as the outcome of complex interactions between non-linear decision making and entities in the unstructured environment. This may cause a "liability gap" due to the difficulties in make judgements. There was an instance at the Fukuoka TNC TV Building where WABIAN-2R fell down on a bumpy surface with tiles angled $2^{\circ}-5^{\circ}$ (forward-axis) downwards (Figs. 11, 12, 13). In this case, WABIAN-2R's Walking Stability Controller dynamically adjusted its body balance based on built-in offline walking pattern and the data received by sensors that monitored the surrounding environment. This resulting autonomous behavior could be seen as a *"Function"* of the product or a *"Decision"* made by WABIAN-2R's Walking Stability Controller by different groups of lawyers. Either or, the result is beyond its designers' expectations and the two ways of definition are very different from a legal perspective.

If defining this behavior as a product misfunction, the physical injuries or damages caused by WABIAN-2R's Walking Stability Controller should be the manufacturer's liability [54]. Conventional production of industrial robots follow ISO 12100's "3-Step" method to ensure its safety. Since hazards in structured environments for industrial robots are relatively easy identify, the first two steps "inherently safe design measures" and "safeguarding and complementary protective measures" could effectively reduce the risks and provide "information for use" to deal with the left part of risks. Next-generation robots' open-texture risk brings a new amount of difficulty in justifying the "product defects". Risks of these robots' behavior are difficult reduce during design and manufacturing stages, and the manufacturers have to provide more comprehensive information regarding usage to avoid liability issues [55]. However, the appropriate amount of information to be provided during sales at this time is still controversial since robotics is still in its infancy. Therefore, a guideline to draw boundaries of liability between users and manufacturers regarding the obligation to provide product information is necessary.

However, if we regarded this autonomous behavior as a decision made by WABIAN-2R's Walking Stability Controller, there is the question of who should afford the tort liability for the physical injuries or damages. As the adaptability of autonomous robots grow, the characteristic of robots as a *"Third Existence"* [56] with autonomous intelligence but lacks self-awareness will become more apparent. By the moment that autonomous robots are fully developed, can we consider the third existence autonomous robots as an pet, with its owner assuming all liabilities? This may be the case since the robot itself lacks the subjectivity to afford legal liabilities [57].

We predict that in future societies, humans and robots can exist alongside each other. However, one of the major disputes regarding third existence robots' civil liability distribution falls into the interlace between whether a robot is a product or an animal. A crucial issue is using technical measures, such as a *"RT Black Box"* event data recorder, to assist liability distribution. There was an example in *Hakata Riverain* shopping mall that WL-16RII carried a person to climb steps (Figs. 14, 15). It could be a complex issue to judge "who" and "which" kinds of civil liability should apply if the WL-16RII accidentally fell down the steps and caused

Fig. 14 WL-16RII carried a person to climb steps in *Hakata Riverain* shopping mall

Fig. 15 WL-16RII carried a person to climb steps in *Hakata Riverain* shopping mall

the passenger or a third party injury. A RT Black Box will be able to record data of both the operating of the robots and the situations of the real world, and thus, it would be easier to tell the causality and the relevance of several parties within one single accident.

6 Conclusion

"Tokku" Special Zone for Robotics Empirical Testing and Development is a necessary method to keep the competitiveness of RT industry through "deregulation" of special measures. In addition, it will be an interface for robots and society or "shock buffer" in the long-term. RT special zone contributes to (1) ensure machine safety, (2) prevent high litigation risks, and (3) ease radical ethics disputes. These could be helpful for regulators to develop their "Robot Law" in separate countries.

In the case study, we focused on the legal impacts to bipedal walking humanoids, pointed out *"Open-Texture Risks"* and how it may bring new liability impacts to current tort laws and product liability laws, specifically on the dilemma between deciding whether a robot should be considered as a "product" or an "animal"? Finally, in addition to legislative additions including *"The Robot Safety Governance Act"*, *"The Humanoid Morality Act"* , and *"Revisions"* for developing the *"Robot Law"*, RT special zone could be a semi-open platform for legislators to conduct the *"Social System Design"* [58] with lower risks for establishing the human-robot coexistence society.

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