Gakken Hills Interdisciplinary Ekiden Competing with Humans, Animals, and Robots

Takuya Fujinaga
Fukuoka University
8-19-1 Nanakuma, Johnan, Fukuoka 814-0180, Japan

Moeko Tominaga
Nishinippon Institute of Technology
1-11, Aratsu, Kanda-machi, Miyako-gun, Fukuoka 800-0394, Japan

Daigo Katayama, Kazuo Ishii
Kyushu Institute of Technology
2-4 Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0196, Japan
E-mail: t.fujinaga.wz@fukuoka-u.ac.jp
www.lsse.kyutech.ac.jp/~sociorobo/gakkenekiden/

Abstract

The number of robots exiting in human living spaces has increased, and interaction between humans and robots has become an important issue. The purpose of this study is to propose a future society where humans, animals, and robots coexist. We organize relay race, or ekiden in Japanese, where they compete together as runners. The competition rules have been established to ensure that each runner can compete fairly. This paper explains the competition rules and discuss the fairness of the rules

Keywords: Robotics competition, Ekiden, Human-Robot Interaction, Robot coexistence society

1. Introduction

Various robotics competitions [1], [2] have been held for social implementation with the development of robotics and artificial intelligence. In these competitions, robots mainly compete about functional performance. On the other hand, the content of robotics competitions changes to more challenging tasks aimed at coexistence between humans and robots [3].

Traditionally, robots have been introduced into industrial environments where safety has been ensured by cages. However, in recent years, the environment in which robots work has been changed to match the daily lives of humans. Research on human-agent interaction [4] and human-robot interaction [5] have aimed to the future society in which humans and robots coexist in harmony. On the other hand, in the universal situation of human society, there are many types of mobile objects: humans, animals, and vehicles. There are few examples of demonstration experiments or discussions about the role of robots in such environments.

We have held “Gakken Hills Interdisciplinary Ekiden” as the opportunity to think about the future society in which humans and robots coexist in harmony [6]. This ekiden is the relay race which humans, animals, and robots compete together on the same field. We held the 8th race on May 13, 2023. This paper describes the competition rules, introduces the characteristics and transition of participants from the 1st to the 8th races, and discusses the fairness of the rules.

2. Gakken Hills Interdisciplinary Ekiden

2.1. *Overview*

We organize this ekiden with the aim of making it a starting point for thinking about the future society in which humans and robots coexist and discussing the directions and challenges of such a society. The 1st race was held in 2014 and the 8th in 2023. Various runners have participated so far: humans regardless of age or gender, animals (mainly dogs) and robots with various movement and operation methods. To ensure fairness for the runners in this ekiden, where a wide variety of runners coexist, we have set our own competition rules. The competition rules have been adjusted every year based on law revision, developments in science and technology, and past competition results. In the following, the current competition rules are described.

2.2. *Rules for all runners*

Runners are divided into categories [P] (Person), [A] (Animal) and [R] (Robot). Category [P] is humans aged 18 years or older, [A] is dogs, cats, and other animals (excluding horses, cows, and other light vehicles) and [R] is robots and electric wheelchairs (excluding flying robots). One of the rules for the [R] sets the use of an electric motor as a prime mover, and electric wheelchairs are classified as the [R].

One team consists of four runners, and, in principle, the four runners are two males and two females. However, the [A] and [R] can be classified as either male or female. Note that within one team, the [A] and [R] can each have up to one runner participating. The race distance differs depending on the category: about 1.6km for the [P] and [A], and about 0.8km for the [R]. For details of the course, see the ekiden website [7].

This ekiden sets advantages so that humans, animals, and robots can compete fairly. The rank in the competition are determined based on the results of applying advantages to the race results. Details of the advantages are stated in 2.4.

2.3. *Rules for robots*

The rules for robot participation are as follows. We set these rules based on Japanese road traffic act.

- The max size is 120cm, 70cm, and 120cm in length, width, and height, respectively.
- An electric motor is used as a prime mover.
- Traveling speed is 6 km/h or less.
- No sharp protruding parts or devices that may cause harm to others.
- The robot has a function that enables it to be stopped quickly in an emergency.

The advantages are applied to different categories of runners in this ekiden, and robots have different advantages depending on their movement and operating methods. Runners in the [R] are classified into the following three classes.

- Direct operation class:
  requires human intervention (e.g. electric wheelchairs, electric kickboards)
- Remote operation class:
  no requires human intervention
- Automatic operation class:
  applicable to three or more of the following five items
  - Do not require a remote controller or other operating device (e.g. human following).
  - Do not require real-time operation by humans (e.g. driving using satellite positioning systems).
  - Make action selections based on environmental recognition (e.g. obstacle avoidance).
  - Have originality (e.g. does not use existing products as a base, or not wheel-based type).
  - Submit a technical poster

Note that in this ekiden, the human intervention is defined as pushing, carrying, or directly touching the robot to adjust its traveling direction by humans.

2.4. *Advantages*

The advantages are determined by the age of the [P], the participation of animals, the robot specifications. The results which are applied the advantages are used to determine the final competition results and the rank. Three types of advantages are defined: age advantage, animal advantage and robot advantage. For the age advantage, let N_p and Age_{total} be the number of participants in category [P] and their total age, respectively. If Eq. (1) is satisfied, Adv_p seconds (Eq. (2)) is subtracted from the race result.

$$Age_{total} > 25 \times N_p \quad (1)$$

$$Adv_p = Age_{total} \times 2 \quad (2)$$

For the animal advantage, let T_A be the race time in the [A]. The unit is seconds. The result R_A seconds which applying the animal advantage is calculated from Eq. (3). Note that the method of calculating R_A depends on the value of T_A.

$$R_A = \begin{cases} \frac{1}{2}T_A + 120 \ (T_A \leq 600) \\ \frac{1}{10}T_A + 360 \ (600 < T_A \leq 2400) \end{cases} \quad (3)$$

For the robot advantage, let R_A be the race time in the [R]. The unit is seconds. The result R_R seconds which applying the robot advantage is calculated using one of Eqs. (4) to (6). Eq. (4) is for the direct operation class ($R_{R(Direct)}$), Eq. (5) for the remote operation class ($R_{R(Remote)}$) and Eq. (6) for the automatic operation class $R_{R(Auto)}$). Note that T_R is between 480 seconds (8 minutes) and 2400 seconds (40 minutes).

$$R_{R(Direct)} = \frac{1}{10}T_R + 390 \quad (4)$$

$$R_{R(Remote)} = \frac{1}{10}T_R + 270 \quad (5)$$

$$R_{R(Auto)} = \frac{1}{10}T_R + 150 \quad (6)$$

The constant number of these equations for the advantages was determined based on the results of previous competitions results to ensure that all runners can compete fairly.

3. Results and discussion

Table 1 shows the transitions in the number of participants from the 1st to the 8th races. The number of runners per team was six from the 1st to the 5th races, and from the 6th race, it was four due to a change in the rules. Regarding the proportion in each race, the category [P] accounts for 70-90%, the [A] was just under 10%, and the [R] was just over 10%. The number of participants in the [A] so far has been 15, all of them dogs. All runners in the [P] and [A] completed the race. The number of participants in the [R] so far has been 45. For the traveling method of the [R], two of the 45 robots were multi-legged or bipedal walking types rather than wheel-based type. For the operating method, six out 45 robots were semi- or full-automatic. Examples of its operation methods were as follows: human tracking using image processing, driving using waypoints, route tracking using the global navigation satellite system, simultaneous localization and mapping (SLAM) using a laser sensor and an inertial measurement unit. Runners who completed the race within the time limit was 35 robots. The multi-legged and bipedal walking types mentioned above were unable to complete the race. Of the six autonomous robots, two were able to complete the race within the time, one using waypoints and the other using SLAM.

Table 1 Transitions in the number of participants

Times	Team	[P]	[A]	[R]
1	13	70	1	7
2	10	52	1	7
3	7	31	3	8
4	6	30	2	4
5	8	43	1	4
6	10	34	3	3
7	12	40	2	6
8	12	40	2	6

Table 2 Average and standard deviation (S.D.) of 8th race results in each category (m: minutes, s: seconds)

Category	Average	S.D.
[P]: male	8m21s	1m33s
[P]: female	10m19s	1m36s
[A]	7m04s	16s
[R]	6m50s	54s

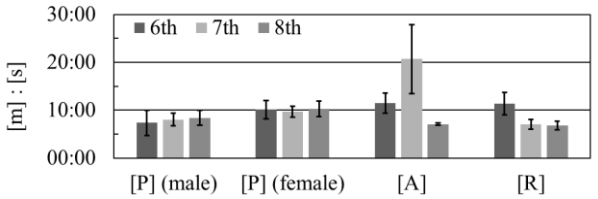


Fig. 1: Average and standard deviation of each race result in each category

Table 2 shows the average and standard deviation of the results for each category in the 8th race. The results of the [A] and [R] were equal to or higher than those of the [P]. Therefore, rules regarding advantages works, and runners could compete regardless of their characteristics. The details are on the ekiden website [7].

This paper discusses the validity of rules regarding advantages. Fig. 1 shows the average and standard deviation of the competition results for each category since the 6th race. The results for the [A] and [R] are the results of applying the advantages. Note that the race distance for the [R] has been changed since the 6th race, so only the results from then on are shown. The results of the [P] have little variation each race. On the other hand, the [A] was at a slow compared to the [P] in the 6th race, and furthermore, the standard deviation was large in the 7th race. The [R] is also at a slow compared to the [P] in the 6th race. However, in the 7th race, the

robot advantage was revised based on the previous race results of the [P], so the results of the 7th and 8th races of [R] and [P] are fair. Based on this result, the animal advantage was similarly revised for the 8th race. In the 8th race, the results of the [A] and [R] were equal to or better than those in the [P]. Therefore, these results show that for each runner to compete fairly, it is appropriate to set an advantage based on a certain standard.

4. Conclusions

We have held the ekiden for thinking about a future society in which humans and robots coexist in harmony. The 1st race was held in 2014, and the 8th in 2023. The rules have been revised for each race based on previous race results and law revision. With the spread of robots, laws regarding robots were established, and the rules for the 8th race were determined based on the laws. This paper showed validity of the rules from race results. We have continued to discuss how robots coexist with humans in future society through this ekiden.

References

1. K. Ishii et al., "Report on the 8th Tomato-Harvesting Competition toward Smart Agriculture", Int. Conf. on Artificial Life and Robotics, pp. 484-488, 2023.
2. H. A. Yanco et al., "Beyond Usability Evaluation: Analysis of Human-Robot Interaction at a Major Robotics Competition," Human-Computer Interaction, 19(1-2), pp.117-149, 2004.
3. H. Okada et al. "What is the Purpose of the World Robot Summit Service Category," J. of the Robotics Society of Japan, 37(3), pp. 218-223, 2019. (In Japanese)
4. S. Yamada et al., "Mutual Adaptation to Mind Mapping in Human-Agent Interaction," IEEE Int. Workshop on Robot and Human Interactive Communication, pp. 105-110, 2002.
5. R. Jahanmahin et al., "Human-robot interactions in manufacturing: A survey of human behavior modeling," Robotics and Computer-Integrated Manufacturing, 78, 102404, 2022.
6. T. Fujinaga et al., "Report on the 8th Gakken Hills Interdisciplinary Ekiden," The 31st Symposium on Fuzzy, Artificial Intelligence, Neural Networks and Computational Intelligence, 2023. (In Japanese)
7. Center for Socio-Robotics Synthesis, Kyushu Institute of Technology, "Gakken Hills Interdisciplinary Ekiden," https://www.lsse.kyutech.ac.jp/~sociorobo/gakkenekiden/ (In Japanese, Access 2023-12-12)

Authors Introduction

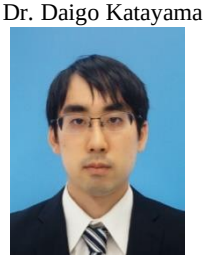
Dr. Takuya Fujinaga

He is an Assistant Professor at the Department of Electronics Engineering and Computer Science, Fukuoka University, Japan. His research interests are in agricultural robots, underwater robots and field robotics.

Dr. Moeko Tominaga

She is an Assistant Professor at the Department of Integrated System Engineering, Nishinippon Institute of Technology, Japan. Her research interests are in multi-agent systems and field robotics.

Dr. Daigo Katayama



He is an Assistant Professor at Kyushu Institute of Technology, Japan. His research interests are in welfare devices, mobile systems, and field robotics.

Dr. Kazuo Ishii

He received his PhD from the University of Tokyo, Japan, in 1996. In 2011, he joined Kyushu Institute of Technology and is currently a professor in the Department of Human Intelligent Systems. His research interests include information communications and marine robotics. He is a member of IEEE.