# KIKS 2014 Team Description Paper

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**Abstract**. This paper is used to qualify as participation to the RoboCup 2014 small size league about team "KIKS". Our robots and systems are designed under the RoboCup 2014 rules in order to participate in the competition. The major improvements in this year are enhancements about the performance and robustness of wheels, electrical circuit and motion control system. The overviews of them are described.

**Keywords**: RoboCup, small-size league, engineering education, global vision

## 1. Introduction

In last year, we made new robots to obtain better performance. But there were some problems for running stability, ring-wheels and electronic circuits etc. of the robots. So we checked them this year, and redesigned for some term mentioned above. In addition we also improved motion control method to obtain better acceleration performance with only little skid. The main topics of development for robot in 2014 model are following terms,

- Improvement of the small ring wheels
- Improvement of the electric circuit
- Improvement of the motion controller on the AI system

## 2. Hardware of the robot

The main configuration for hardware is basically same with the 2013 one. The wheel was tried to improve for a stable travelling performance. In 2014 model, we also use the brushless motors (maxon EC45 flat) as the driving motor, like many teams. For the dribbling device, we use the brushless motor (maxon EC-max22) again. Each robot has three solenoids. One is for straight kick and the other two are for chip kick. The robot is able to shoot the ball at a speed of over 10[m/s], however, it is down to 8[m/s] to keep to the regulations. The height and maximum projection on

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the ground for the robot is 148[mm] and 178[mm], respectively. And the maximum percentage of ball coverage is 18%. The specification of the robot is summarized in Table 1.

Table 1. Specification of robot for 2014 model

| | 2014 version |
|---|---|
| Weight | 2.3kg |
| Main material | Aluminum alloy |
| Driving motor | maxon EC45flat (30watt) |
| Gear ratio | 3.6 : 1 |
| Wheel diameter | 56mm |
| Number of solenoids | Straight kick: 1<br>Chip kick: 2 |
| Straight kick power | Ball speed of 8[m/s] |
| Chip kick power | Max 3.0m away from robot under the condition of initial angle 40° |

### 2.1 Travelling performance of the wheel

Since 2011 competition, we have used the brushless motors as same as many teams do. But, there was a problem in previous wheel for performance of straight-running stability of the robot. That is, our robots were not able to run straight stably under the condition of max speed of $2ms^{-1}$ and acceleration of $3ms^{-2}$. Figure 1 shows the present wheel.

Fig. 1 Present wheel

The new small tire is constructed with wider urethane material, metal pin and washers as shown in Fig. 2. A previous wire shaft connected with all small one is changed into each metal pin in new wheel. By using of two washers in small wheel's house the friction of small tire is decreased drastically. The urethane tire with cross-section of rectangular is effective to enhance the friction between wheel and playing field. As the results of wider width of small tire and more precise approximate cir-

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cumference in new wheel, the robot can run smoothly and turn quickly. In addition, the resin material as outside shell for wheel is easy for cutting work, and is effective for realization of high-speed rotation due to its light weight.

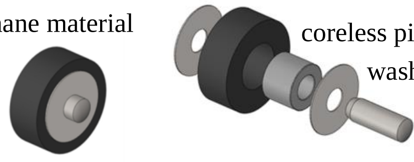


Fig. 2 Component of small tire on wheel

It was manufactured new-type wheels in last year. But, the material of small tire of wheel, i.e., urethane rings with hardness of SHORE A 70 were frequently worn and/or broken in play. As the results, it caused adverse effect for the performance and maintenance of robot. So, we tried to search and find the suitable form of wheel and materials of small tire to solve this problem.

As well as known, X-ring is a popular material for small tire. However, it is not available easily for X-ring, because the difficulty of getting and expensiveness of it in Japan. We have some X-ring for evaluation, but its size is different from our previous small tire. So, we manufactured the experimental wheel to evaluate for the performance of materials of small tire with no change of diameter of the wheel. It is shown in Fig. 3. Through these wheels, we tried to investigate the difference among X ring and some materials for their performance.

Fig. 3 Comparison of experimental wheel (left) with present one (right)

First, we evaluated about the performance of experimental wheel by using of small tire which is same condition (urethane material with hardness of SHORE A 70). Figure 4 shows the result compared the velocity characteristic of experimental wheel with the present one. It appears the average velocity under the condition of thirty back-and-forth straight motions when the command value of trapezoidal acceleration is sent to robot. The agreement of result of both wheels is good. It means that the experimental wheel is valid for evaluation.

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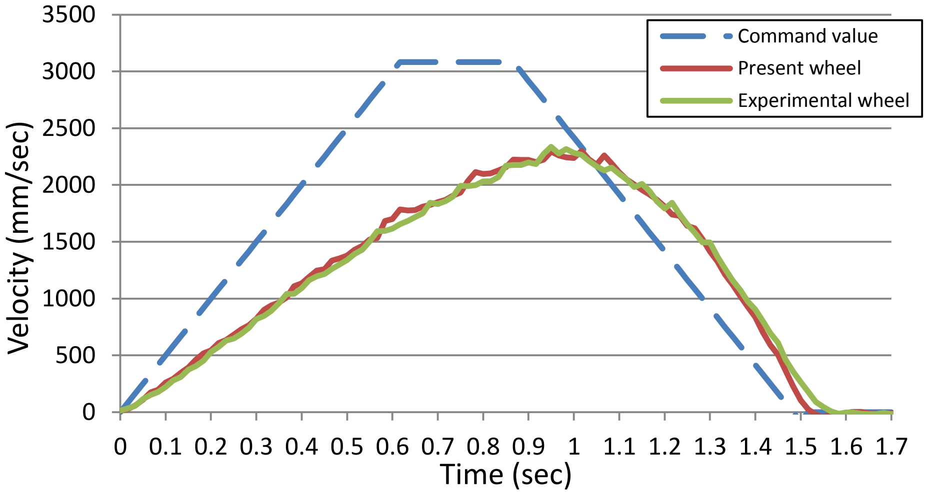


Fig. 4 Characteristic comparison of present and experiment wheel

Next, we investigated about similar characteristics of (a)X-ring, urethane with hardness of SHORE A (b)70 and (c)90, (d)polychloroprene, (e)nitrile rubber for small tire of wheel. The results are shown in Fig. 5.

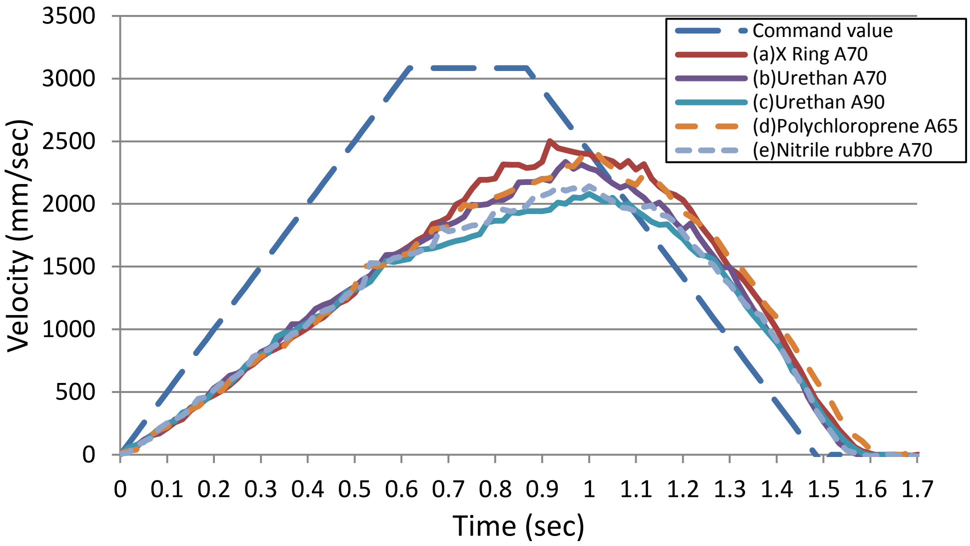


Fig. 5 Velocity characteristics of various materials for small tire

In Fig. 5, X-ring indicates the best performance among all materials. The (b)urethane A70 and (d)polychloroprene are second best one to X-ring. Thus, we made experiments for durability of small tires made from their materials under the

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condition of continuous rotation motion for twenty minutes. The results are shown in Fig. 6 and Fig. 7. There are no serious attritions to expand to the breaking of small ring in those figures. Therefore, they show that the performance of present wheels are good within the range of our experimental confirmation. But, we can not confirm it in real game. So, the performance shoud be confirmed as soon as possible.

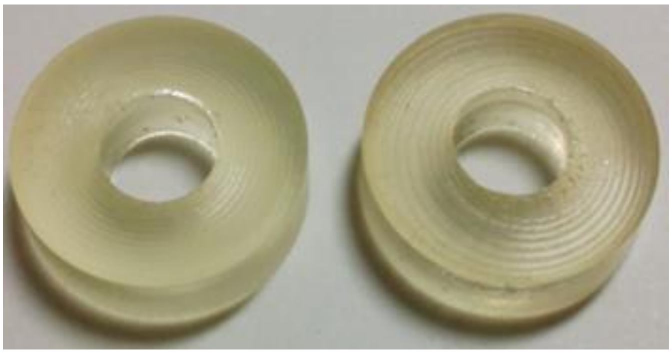

Fig. 6. Small tire of urethane 70A , before experiment (left) and after that (right)

Fig. 7 Small tire of polychloroprene, before experiment (left) and after that (right)

## 3. Electrical design

The electronic circuit is mostly same with last year. The circuit block of base board and FPGA are shown in Fig. 8, respectively.

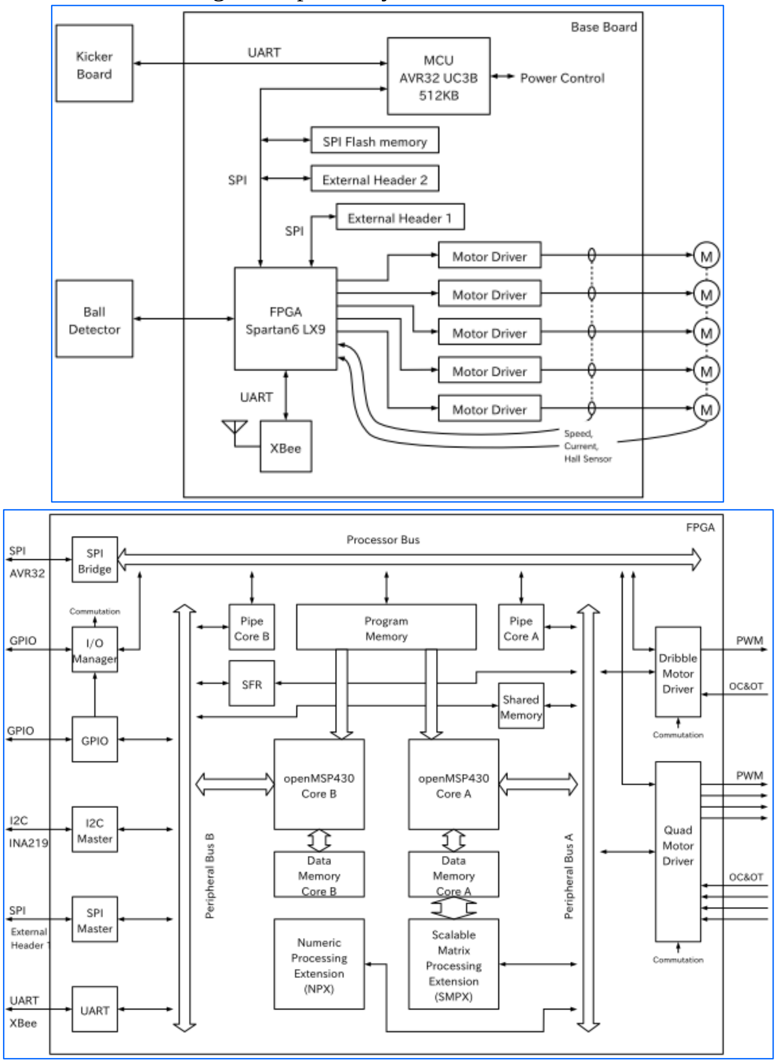


Fig. 8 Circuit block of base board (upper) and FPGA (lower)

### 3.1 PC Software for New FPGA Board

We developed software to obtain the information of new circuit. All data (e.g. data such as battery voltage, capacitor voltage, angular velocity of each motor, and a current value etc.) of a circuit can be observed in this software. These data can be outputted to the file of CSV or VCD format, and also evaluated with gnuplot.

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The execution screen of the software is shown in Fig. 9 and the capture image of gnuplot is shown in Fig. 10. This software can also write into micro-computer in FPGA with HEX format program by means of two methods. One is a mode of completely stored in ROM, and another is that of temporarily stored. The temporary store means that it will be back previous program when the power supply is shut down. By applying this method, it will be convenient for debugging.

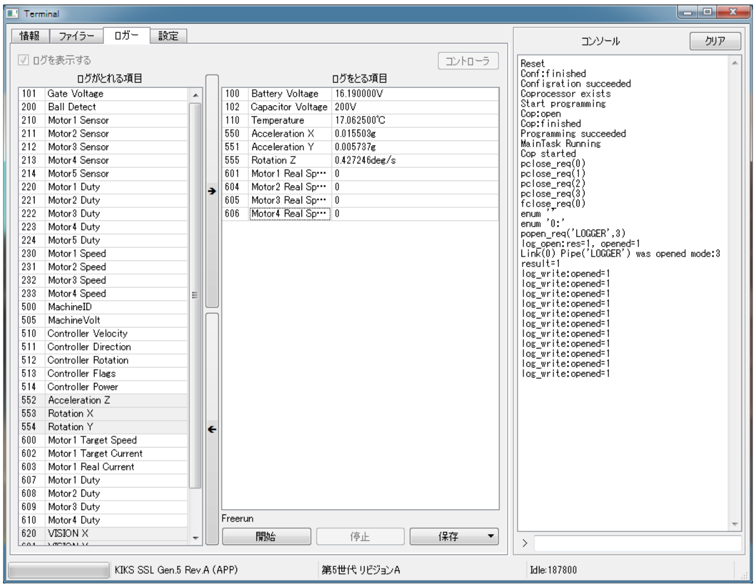

Fig. 9 Execution screen of software to obtain data for robot

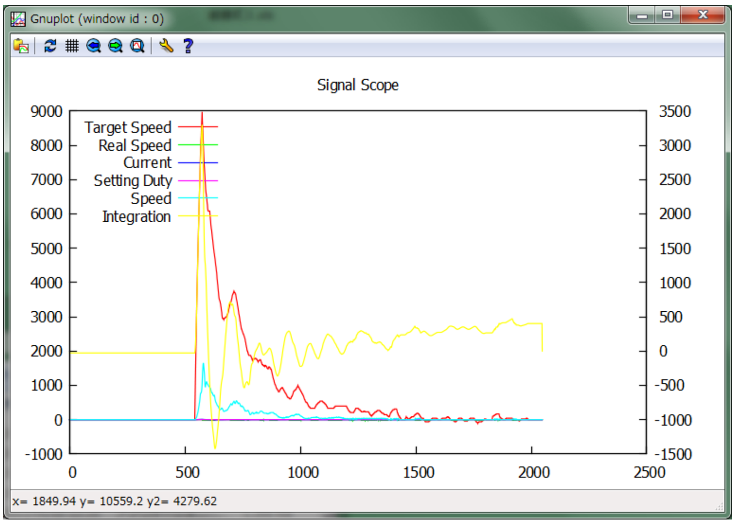

Fig. 10 Capture image of gnuplot

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### 3.2 Inertial Measurement Unit for New Circuit

We built a scalable system for new circuit. One of them is a terminal connector for add-in boards in a circuit. It is necessary for advanced control of robot to mount IMU (Inertial Measurement Unit). The pictures of new designed IMU and the FPGA board are shown in Fig. 11 and Fig. 12, respectively. Thus, now we can use gyroscope sensor and accelerometer by using this add-in board. We have a plan to try new control system by using the value from IMU with software descried in §3.1.


Fig. 11 new IMU circuit

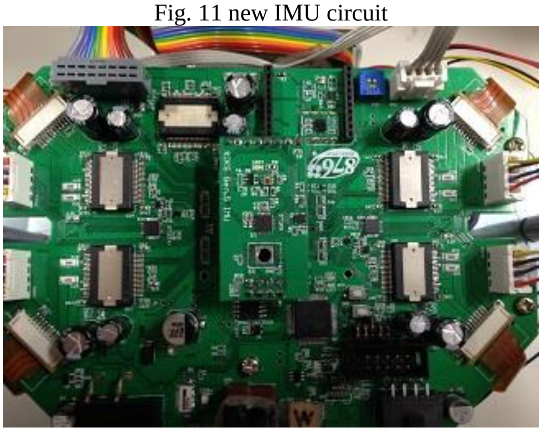

Fig. 12 IMU circuit mounted on FPGA

### 3.3 Voltage booster circuit

The DC-DC converter is used to boost up voltage for the solenoid. The input voltage of 16V is converted to 200V output. This chopper circuit is controlled by PIC in each robot. In kicking device, the output voltage of 200V is charged in 3mF capacitor. The time to charge up to 200V from 16V is about 3 seconds.

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## 4. Software design

Our AI server is called SIS (Strategy Information System). The SIS consists of four threads as shown in Fig. 13. There are "Game Thread", "Sender Thread", "SSL-Vision Receiver" and "Referee Box Receiver". The analysis of strategy and action for all robots are executed in "Game Thread".

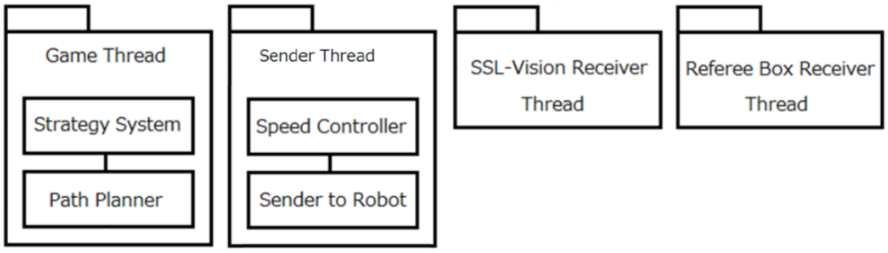

Fig. 13 Structure of SIS

In 2014, we tried to modify the structure of "Strategy System" in "Game Tread", and improve the "Speed Controller" in "Sender Thread".

### 4.1. Improvement of the structure of strategy system

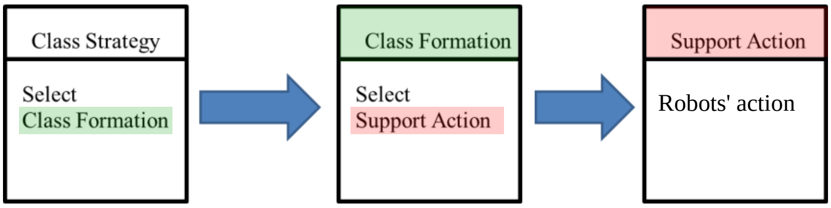

Fig. 14 Previous structure of strategy system

A previous structure of the "Strategy System" shown in Fig. 13 is constructed from three modules. It is shown in Fig. 14. First, it is chosen the "Class Formation" corresponding to the Referee box's signal in "Class Strategy". In next "Class Formation", it is chosen the "Support Action" corresponding to the game situation for each robot. Finally, the "Support Action" makes a decision how do robots work. For example, There are actions such like [kick a ball] and [move a robot] in the "Support Action" library. When the "Class Formation" decide to make kicking a ball for a robot, it chooses [kick a ball] in the "Support Action" against robots.

In previous structure, the "Class Formation" decided all robots' action analyzing from the situation of game. But, we have to construct more flexible "Class Formation" to promote a smart and intelligent gameplay. It is difficult to develop more complex "Class Formation" because it is required many "Support Actions" and branch condition for intelligent behaviors. It is also hard to reuse the previous program. Therefore, we tried to introduce newly-proposed "Class Agent" in new strategy system as shown in Fig. 15 to develop program more efficiently.

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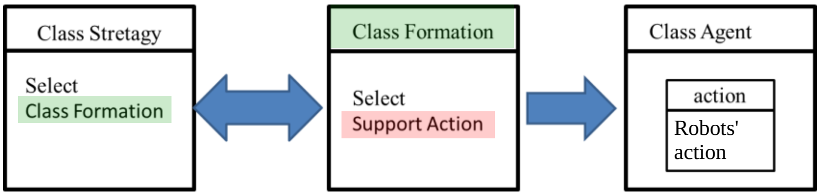

Fig. 15 New structure of strategy system

The "Class Agent" is a class that selects appropriate Support Action depending on given role in game. In new structure of Fig. 15, the "Class Formation" decides only each robot's role. The knowledge and intelligence to play a given role is kept in the "Class Agent". As the results, we could develop more efficiently programs which have flexible intelligence by introducing of this structure.

### 4.2. About controller of Robot

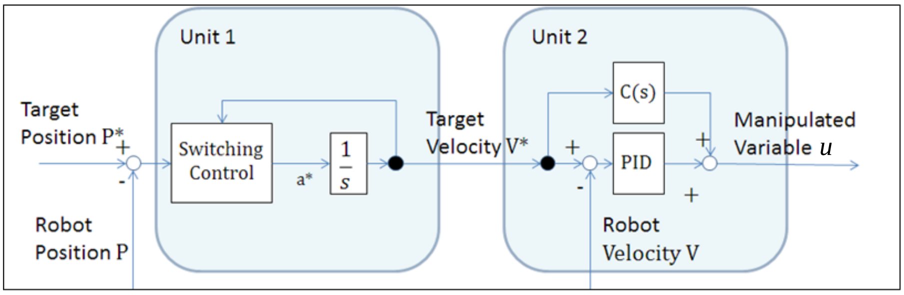

Fig. 16 The robotic control to last year.

Last year, we developed controller which has two control units as shown in Fig. 16. To realize stable and speedy robot's motion, it is necessary to control within the robot's limitation of acceleration. It is achieved by using sliding mode control that is one of nonlinear control on the basis of explicit limitation of acceleration. We can get the target velocity $V*$ from target position $P*$ and current position $P$ in Unit1 of Fig. 16. The Unit2 is enable us to know current velocity $V$ following $V*$ by using two-degree-of-freedom control. In case of use of this theory, it is required a high following-performance for robots to make $V \fallingdotseq V*$ in Unit 2. However, we could not construct appropriate structure of Unit2 last year. In this year, we tried to identify ideal robot model by using genetic algorithm, and design ideal Unit2 on the basis of the results after that.

#### 4.2.1. Identification of model by using Genetic Algorithm

Velocity of the robot is expressed in transfer function as following equation,

$$V = \frac{ks+t}{s^2+2\zeta\omega_n s+\omega_n{}^2}u \qquad (1),$$

where, $\zeta, \omega_n, k, t$ are constant coefficients that define characteristics of robot, and $u$ displays the manipulated variable in Fig. 16. Eq. (1) is equal to transfer function of

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speed control of motor with PI control. In this system identification process, the genetic algorithm (GA) is used to get most probable parameters of $\zeta, \omega_n, k, t$. Figure17 shows a program flow of system identification process with GA.

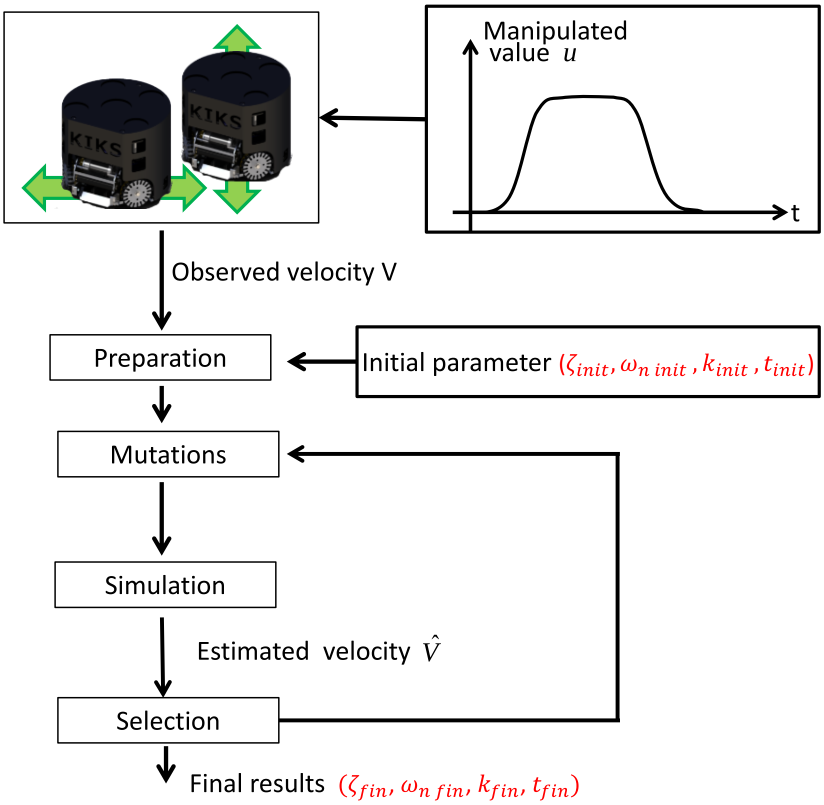


Fig. 17 Identification process of parameter $\zeta, \omega_n, k, t$ by using GA

At first of identification, the robot's velocity $V$ is investigated when the trapezoidal acceleration command value is given as shown in Fig. 18. Next, it is analyzed $\zeta, \omega_n, k, t$ that robot's estimated velocity $\hat{V}$ follows with trapezoidal velocity $V$. The results for experiment of 1st and 400th generations on GA are also shown in Fig. 18. It is found that the estimated velocity $\hat{V}$ is good agreement with the observed value $V$ in Fig. 18. All control logics in SIS are made by using results of identification mentioned above.

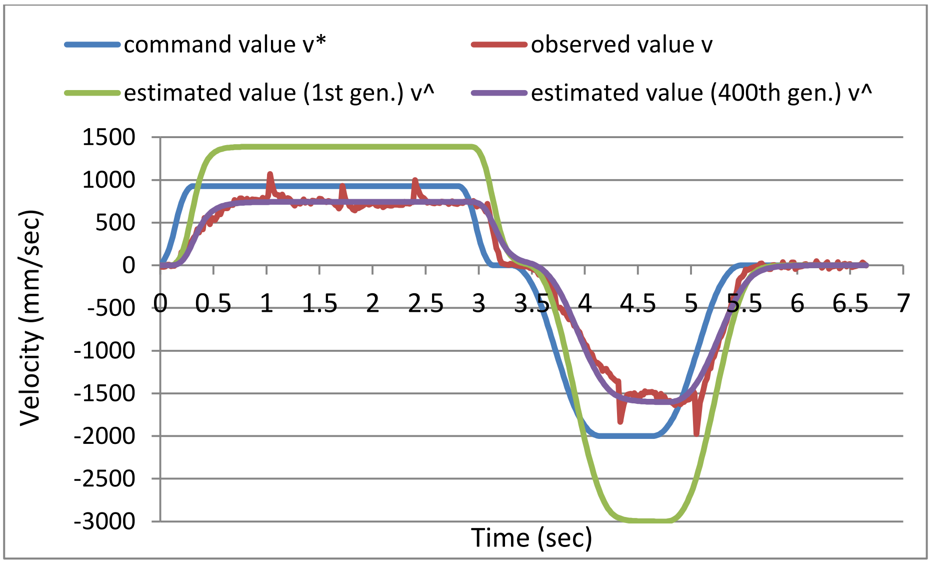

Fig. 18 Result of optimization by applying GA

4.2.2. Optimization of Unit2

We identified the appropriate parameter of control model for Unit2 in §4.2.1. As mentioned above, the Unit2 ensure following performance by using two-degree-of-freedom control. It is necessary to be equal to one for value of whole transfer function of nominal plant in order to making $V^* \fallingdotseq V$. Thus, $C(s)$ in Unit2 is designed in following eq. (2) as reverse expression of control system.

$$C(s) = \frac{s^2+2\zeta\omega_n s+\omega_n{}^2}{ks+t} \qquad (2)$$

By using eq. (2), whole transfer function is theoretically equal to 1. In fact, however, the parameters $\zeta, \omega_n, k, t$ derived in GA are not strictly true. So, the Unit2 uses PID control to reduce influence of various errors. A gain of this PID control is determined from pole assignment of nominal plant through a trial and error process.

## 5. Conclusions

Our robots have been continuously improved in every year. As the results, the motion and the performance of the robots are getting better.

We hope that our robots will perform better in this coming competition.

adfa, p. 12, 2014.