Team Description Paper 2021

RCJ Soccer League - LightWeight

Ryotaro Nishi, Keita Sugimori, Kota Minami, Kenichi Taito,
and Utahito Masuda(mentor)
Sanda Gakuen High School Physics Club
2-13-65, Minamigaoka, Sanda Shi, Hyogo Ken, 669-1535, Japan
https://www.sandagakuen.ed.jp/
https://www.youtube.com/channel/UCfuTCNfLAc4_XWa-yv2wtcw/featured

Abstract :

We created innovative gear heads by 3D printer, which resulted in a significant weight loss and cost reduction. This paper contains a lot of information that overturned the common sense of Light Weight league robots, such as the fact that we were able to use heavy motors that were not supposed to be used. We also wrote about the innovative strategy of separating the Attacker and the Keeper in the text.

Introduction :

SG-Re_X was formed in April of 2020. SG-Re_X is a team in Sanda Gakuen High School which was founded in 1912. SG-Re_X won RCJ Japan Open 2021 Soccer LightWeight.The team members are Ryotaro Nishi, Keita Sugimori, Kota Minami, and Kenichi Taito.

Ryotaro Nishi	Keita Sugimori	Kota Minami	Kenichi Taito
Captain	Design	Circuit	**Mechanic**
Circuit	3D Printer	Communication	Design
Camera		Music	Program
			Circuit

Fig.1 Roles and responsibilities for the 2021 season

As you can see, each member of our team has an indispensable role to play in making the robots. If we cannot fulfill even one of these roles, the robots do not work. Therefore, our team was able to control the robot perfectly by sharing the development status and communicating well with each other.
In RoboCup Junior, when robots were made by dividing the work(circuitry, design, programming, etc), it is not uncommon for misunderstandings and problems to occur within the team due to differences in the progress of each person in charge. SG-Re_X, however, does not have such problems.
The reason for the high level of teamwork in SG-Re_X is that in the 2018-2020 season, everyone in this team had built a robot in the past. Everyone in this team had experienced all the design, circuitry, and programming. This allowed us to build the robot smoothly even though we had to divide up the work because all team members have some understanding all of the design, circuitry, and programming.

RoboCupJunior result of team members.

RoboCupJunior Japan Open 2018 Nippon League Soccer Beginners 1st.
RoboCupJunior Japan Open 2019 Nippon League Soccer Beginners 1st.
RoboCupJunior Japan Open 2020 World League Soccer Light Weight
RoboCupJunior Japan Open 2021 World League Soccer Light Weight 1st.

We used to build robots with breadboards, universal boards, and 2D CAD. So we had a very hard time with bad contacts and poor maintainability. However, since we formed this team, we have been using Ki-Cad to design the printed circuit board and Fusion360 to design the main frame and parts to make the robots more complete.

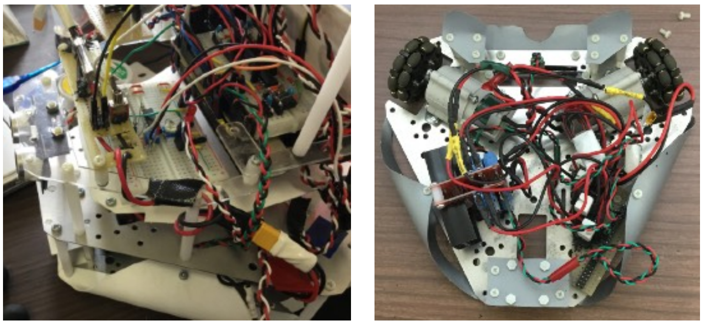


Fig.2 2018~2020 robots

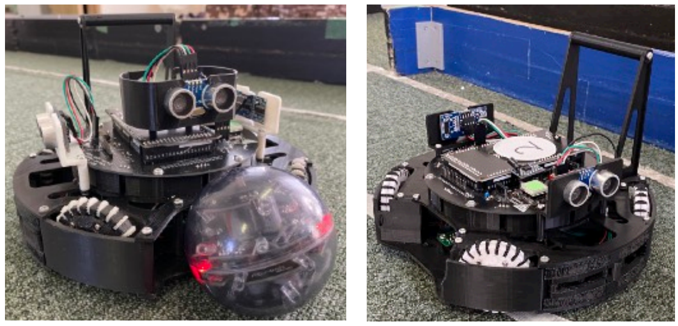


Fig.3 2021 JapanOpen robot

Do you think that you have to spend a lot of money to make a good robot? Do you think that you can just use the same parts as the top teams in the competition? In fact, many of the top teams in the competitions use robots with a high degree of perfection using expensive parts. However, that's no fun even if you can win.
SG-Re_X is the first team in the world to change and revolutionize the common sense of RoboCupJunior.
By making most of the parts by us own and using a variety of first an idea in the world, they succeeded in building a robot at the amazingly low cost of about 160＄per unit. If you have an idea and the ability to make it happen, you can make a robot regardless of money!
We are not denying the need to spend a lot of money to make a robot. We just wanted to change the stereotype that you have to spend a lot of money. This change in mindset will make it easier for more people than ever to participate in RoboCupJunior, and since we are making the robots ourselves to keep cost down, we will have more knowledge about the various parts.

For example, the selection of the motor also shows our characteristics.
We decided to use a motor that other teams are not using. So, we went to the electric street in Nihonbashi, Osaka with our team members and looked at various motors. Among them, we found a Maxon motor with an unknown model number. It had amazing speed and strong torque that no robot could match, but it was only 300 yen(about 3dollars) each, so I decided on it right away. However, there was one major problem with this motor: its weight. Weighing 117 grams each, it was quite difficult to use this motor in the LightWeight league. However, with the help of SG-Re_X's technology, ideas, and realization, we developed a revolutionary gearbox that made it possible to use this motor. We have gained tremendous speed and power.

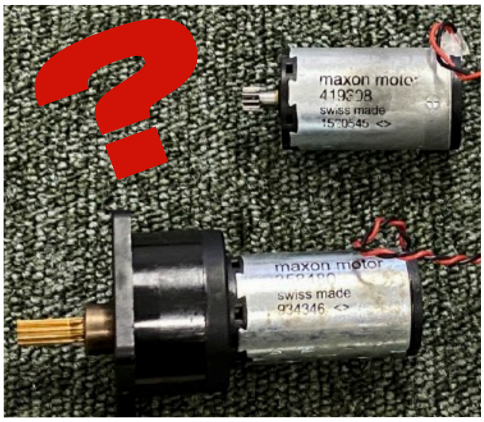


Fig.4 The Maxon motor

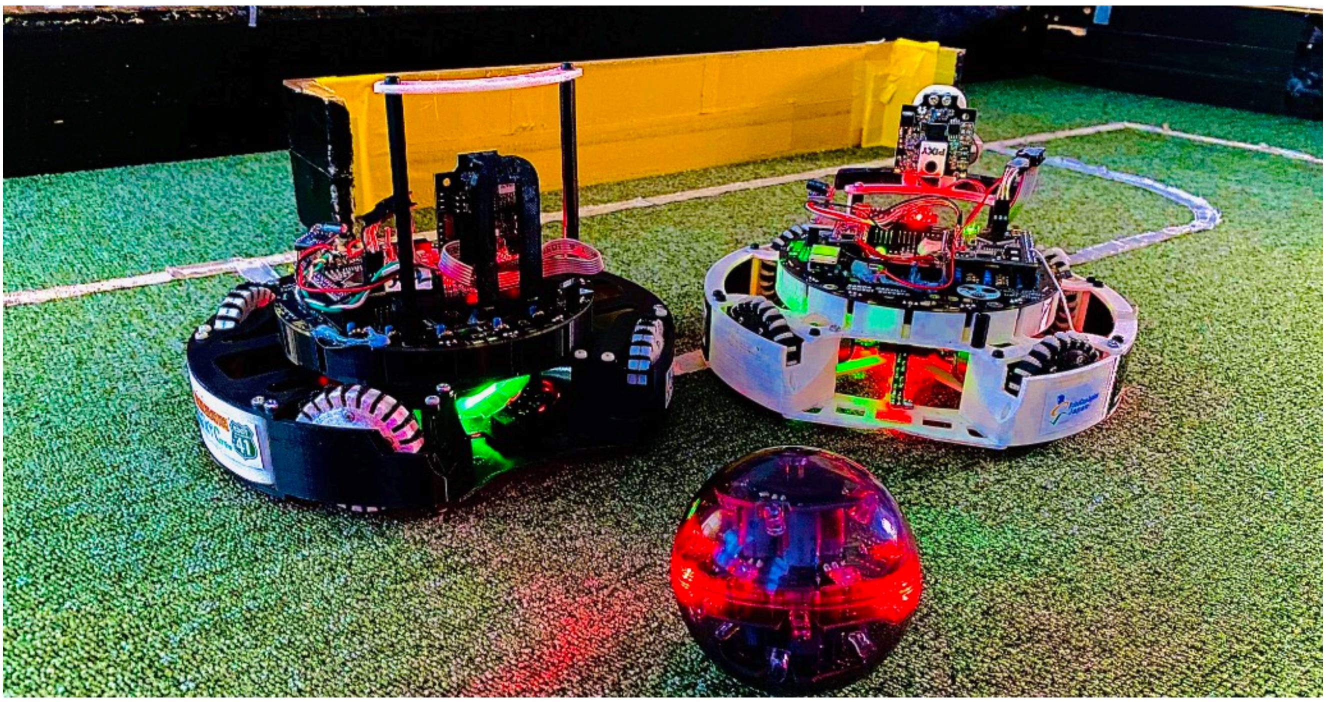


Fig.5 SG-Re_X

Robots and Results: Hardware

1.Circuit

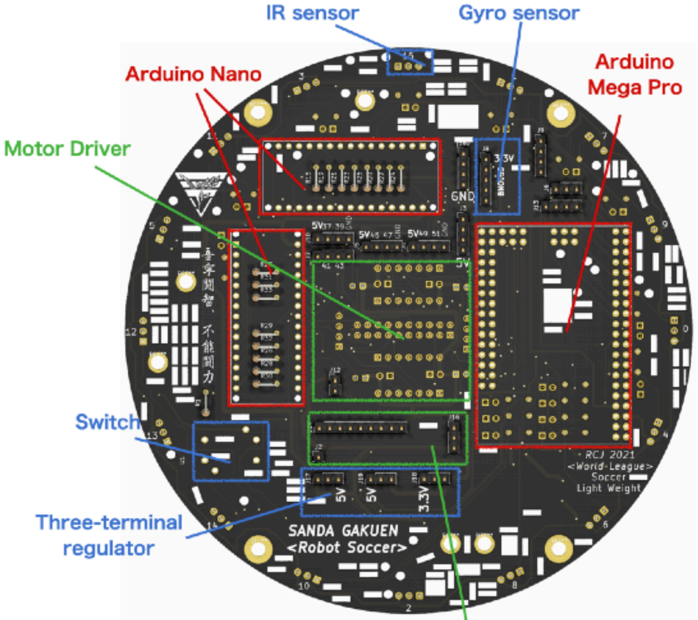


Fig.6 Main-substrate

This mainboard contains most of the circuitry needed to run the robot. This reduces the number of wires, reduces contact defects, improves the design, and reduces weight.
It also features thicker power supply lines to reduce heat generation, and a three-terminal regulator to supply 5V and 3.3V for line sensors and LEDs and a gyro sensor.
This helps to reduce the load on the Arduino Mega pro.
We also drilled a lot of small holes in the board to reduce weight and improve air circulation. Furthermore, by installing a large tact switch with LEDs, we were able to improve the operability of the system, and by making the screw place a land, we succeeded in reducing the noise.

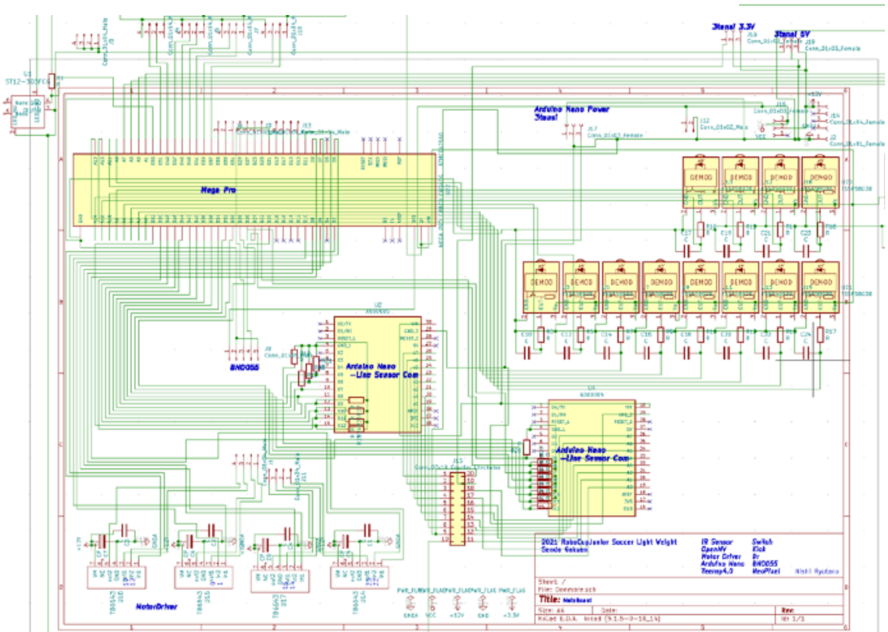


Fig.7 Main-substrate schematic

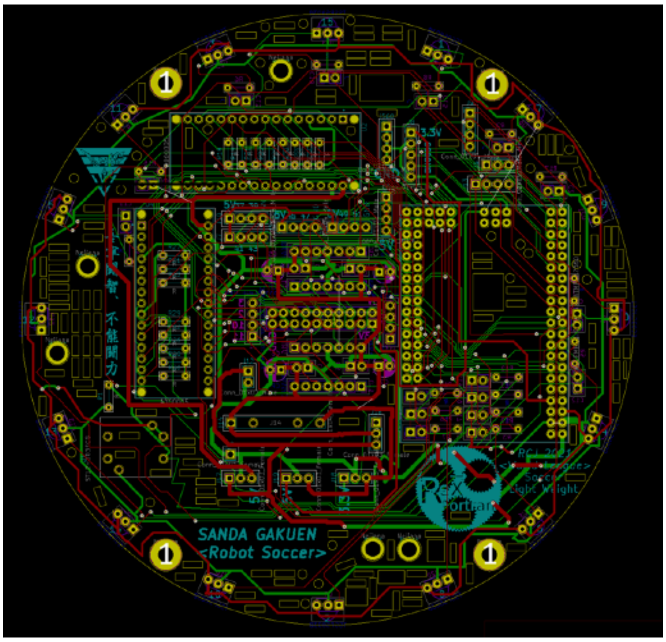


Fig.8 Main-substrate PCB

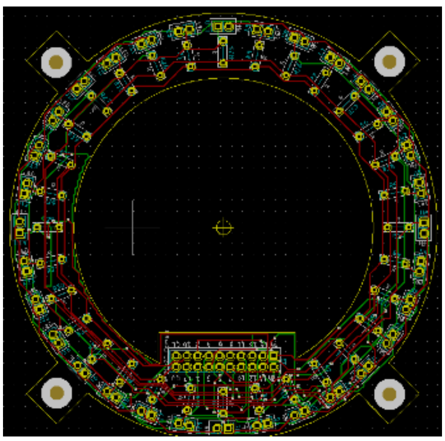


Fig.9 Line Sensor board PCB(ring-shaped)

The power supply is separated into 3.3V for LEDs and 5V for line sensors.This helps prevent heat generation. Also, I was able to keep the wiring clean by aligning the pin headers with main-substrate.

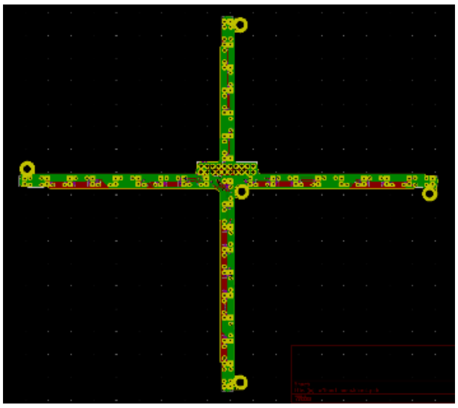


Fig.10 Line Sensor board PCB(cross-shaped)

One of the weaknesses of the cross-shaped line sensor substrate is that it increases the weight of the board. However, we were able to reduce the weight considerably by designing the board with a width about the same size as the sensor.

2.Design

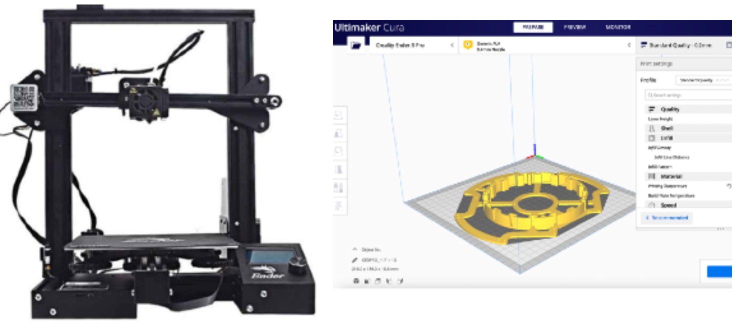


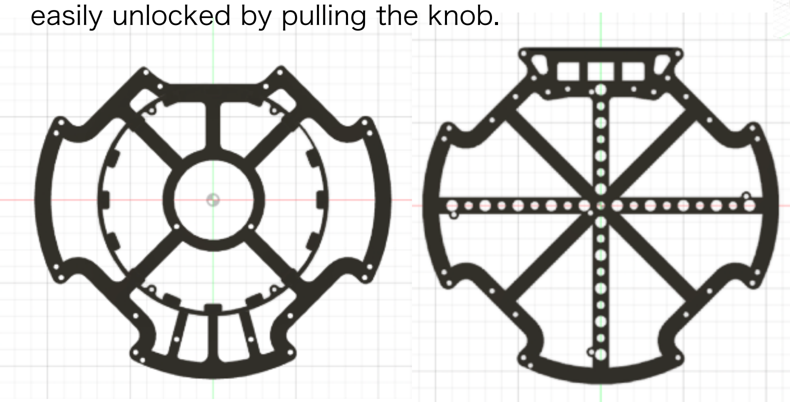
Fig.11 3D printer

Almost all parts of our robots are made with 3D printers. There are so many teams that make robots using materials such as aluminum, carbon, and duralumin. However, this requires a very expensive CNC, is difficult to process, and is also dangerous work. With a 3D printer, however, it is not only safe, but also easy to process, well-designed, and inexpensive to make.

2.1 Retractable cover

This has made it possible to change the battery smoothly. By using the force of the spring, the claw can be caught in the cover and locked. It can also be easily unlocked by pulling the knob.

Fig.12 The Retractable cover



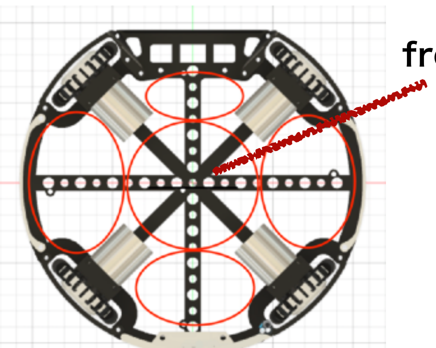
(a) Top plate **(b)** Bottom plate

Fig.13 The plate of our robot

2.2 Extreme Weight Loss.

Our team is using a motor that is too heavy to be used in the LightWeight league, so we put a lot of effort into reducing the weight of the robot.The upper plate is designed as an integral part of the IR sensors cover to increase its strength. In addition, by drawing lines like a spider's web, we were able to develop a frame with sufficient strength even with a drastic weight reduction.

2.3 Free space in the robot



free space

By storing the battery inside the body, the robot's center of gravity was lowered significantly, allowing for more agile movements.
This large space would not have been possible without the self-made gearbox introduced next. Also, the wiring of the Line sensors is now easier to do.

Fig.14 Free space in the robot

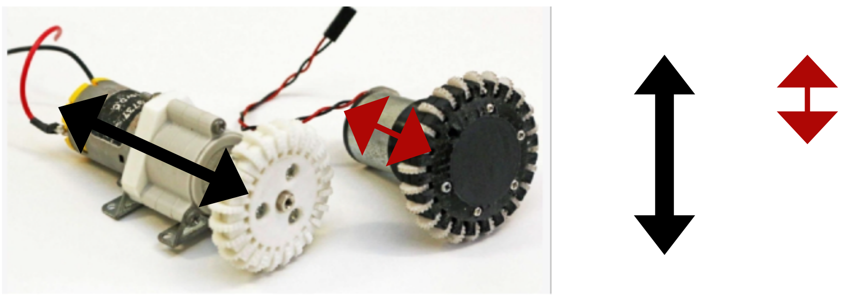


Fig.15 conventional gear box and Gear Box

The Gear box will be a shock to the RoboCupJunior world in the future. Next year, the diameter of the robots in the RCJ Open League will be changed from 22cm to 18cm, which means that some of the motors used so far will not be able to be attached to the robots. However, with this innovative gearbox, players can choose from a variety of motors. I have no doubt that this gearbox will play an important role in next year's not only Open League, but also LightWeight League.

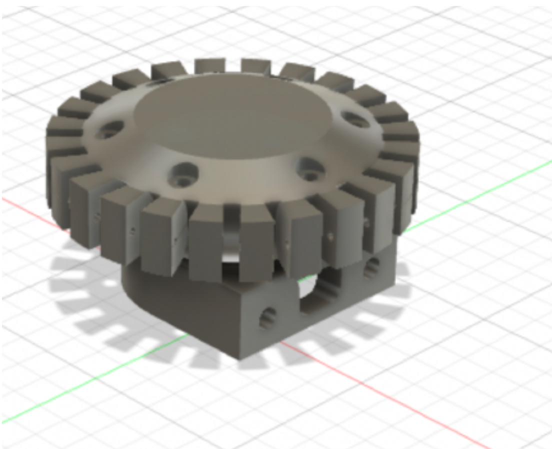


Fig.16 The Gear box

2.4 Gear box

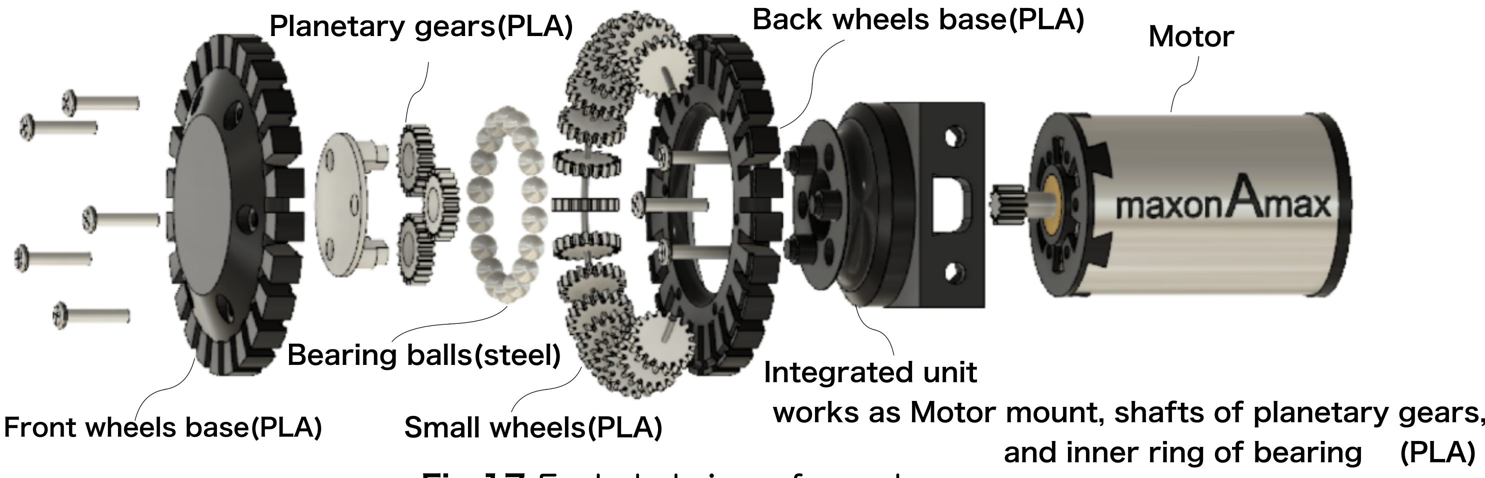
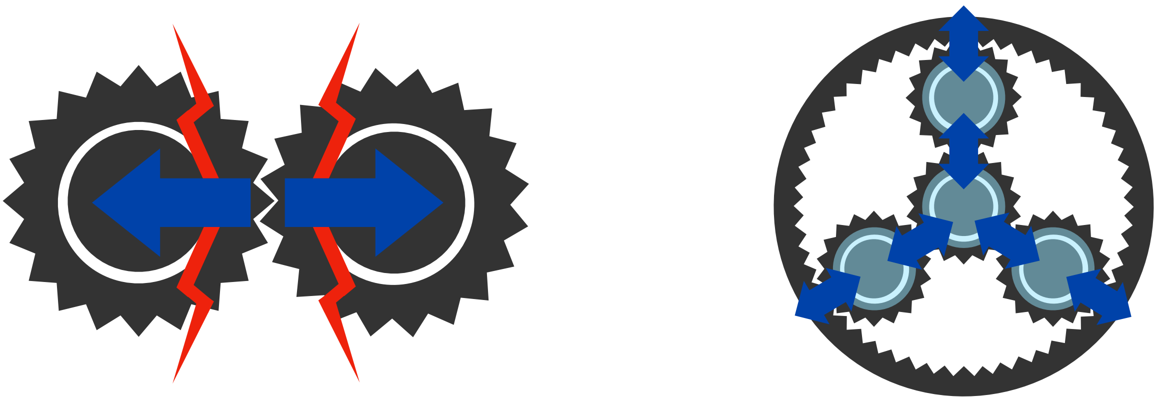


Fig.17 Exploded view of gear box

We made a gear box by 3D printer. It's more compact and lighter than conventional gear boxes. In addition, it costs only 300 yen(about 3 dollars) and it has strong durability.



(a) Spur gear

(b) Planetary gear

Fig.18 Spur gear and planetary gear

Our gear box has planetary gears and assembled with bearing. Fig.18 (a) shows an example of gear mechanism with spur gears. Repulsive force between two gears gives strong stress to the shafts. On the other hand, planetary gear mechanism can cancel shearing stress to the shafts as shown in Fig.18(b). Also, planetary gear mechanism is suitable for making a compact gear box.

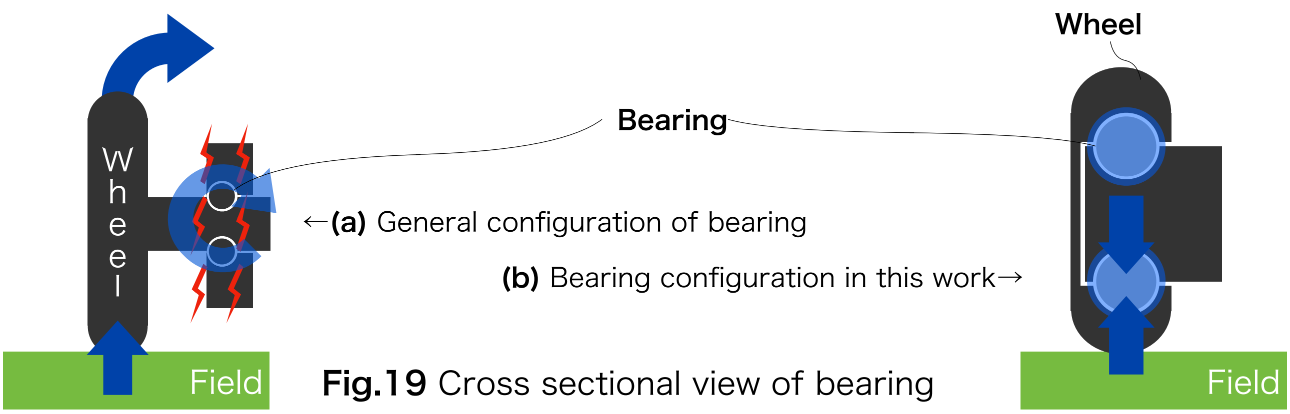


Fig.19 Cross sectional view of bearing

We put bearing balls into the gear box. When you use general configuration shown in Fig.19 (a), bearing system suffers not only radial load, but also axial load. The bearing configuration we developed can eliminate axial load (Fig.19 (b)). Planetary gear mechanism and bearing configuration developed in this work enable us to make a gear box with not so strong material like PLA.

Fig.20 Sectional view of gear box

Using a special construction we developed, we could make a gear box very compact(Fig.20). In our gear box, the internal gear is made together with the front wheels base. And the shafts of planetary gears and the inner ring of bearing are made together with motor mount. These special parts enable us to make it so compact that the gear box and the bearing are completely included inside the wheel.

3.Software

3.1 Ball tracking

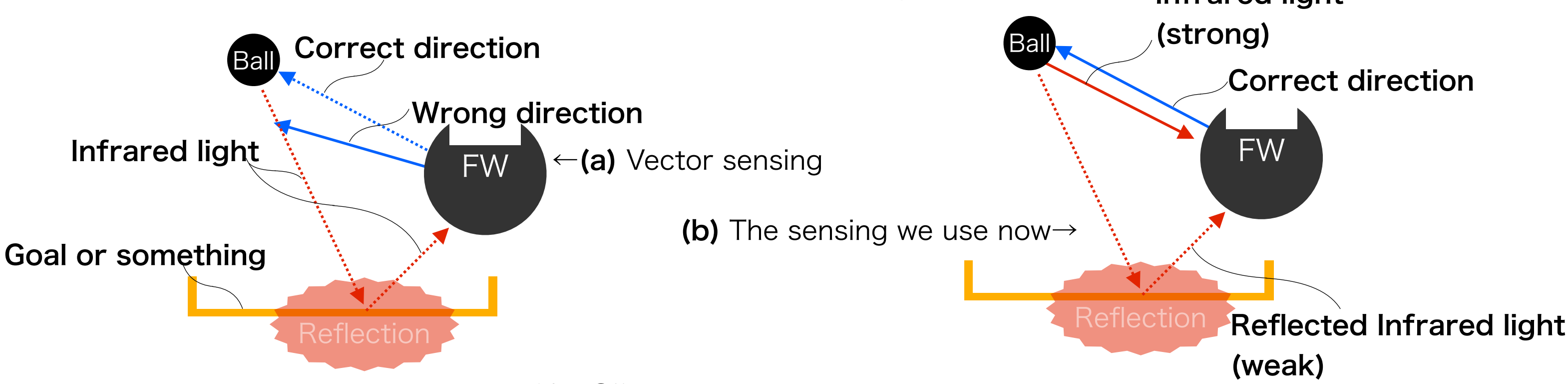
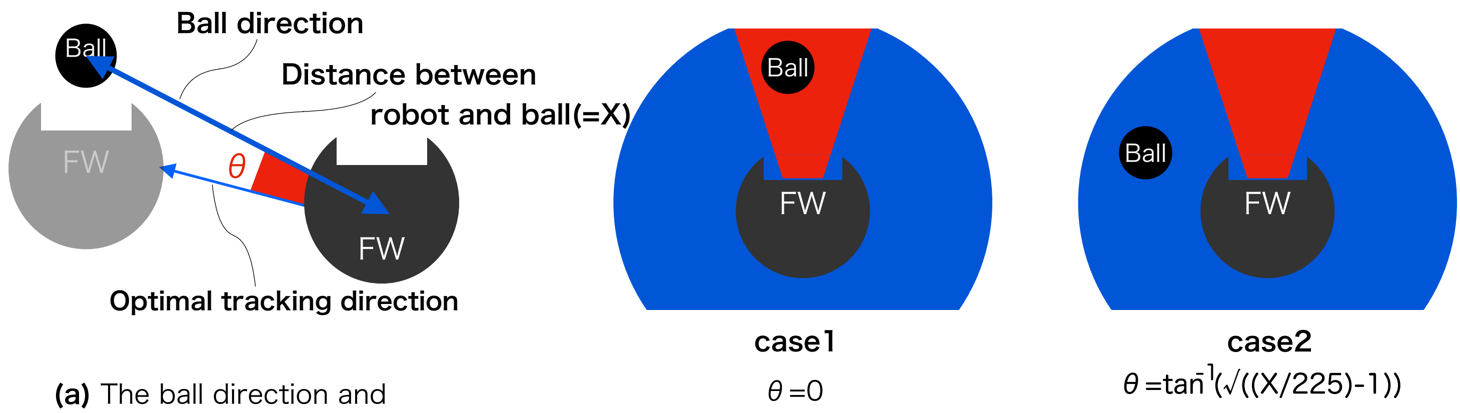


Fig.21 Ball direction sensing

Our robot had used vector sensing to detect the ball until the Japan tournament. But we faced a difficulty that the it is affected by the scattered infrared light(Fig.21). Now, our robot compares the output of IR sensors, recognize the direction of the ball out of pre-determined 16 patterns. Thus, the robot works more stable than before. Also it detects the distance between the robot and the ball by counting the number of responding sensors.



(a) The ball direction and the optimal tracking direction

(b) Calculation method to follow the ball

Fig.22 The way to chase the ball

The direction of the ball detected by the robot and the optimal tracking direction is a little different. This time, we defined the angle difference as θ (rad), and define the distance between the robot and the ball X(cm)(Fig.22 (a)). We considered the method of calculation to follow the ball(Fig.22(b)). This is based on the mathematic model(Fig.23). Our robot is about 22cm in diameter, the ball is about 7cm in diameter and the robot keeps 1cm gap from the ball. So the calculation is like Fig.22(b). But we faced a difficulty that the function of $\tan^{-1}$ needs long processing time. So we simply approximated it by a proportional calculation(Fig.24).

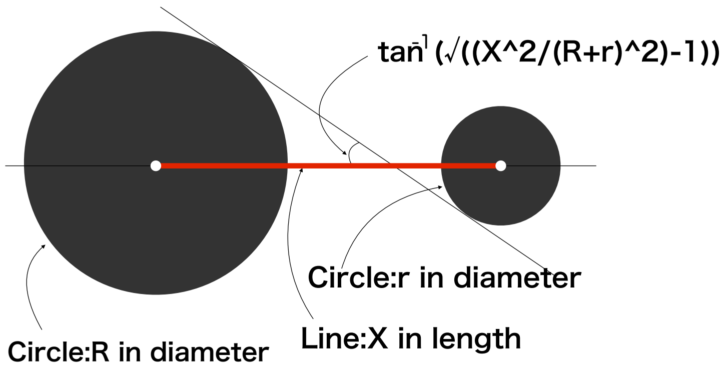


Fig.23 mathematic model

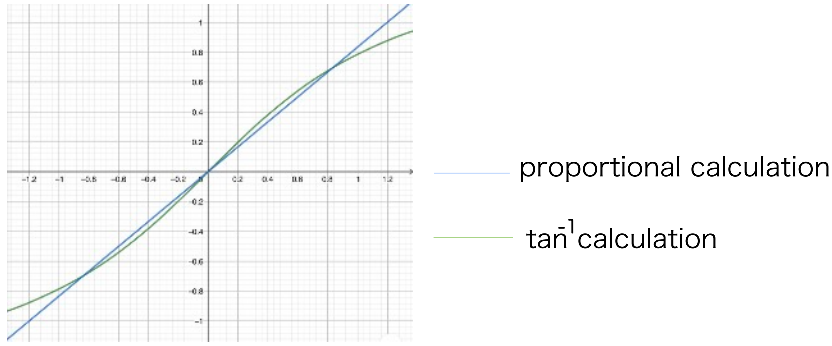
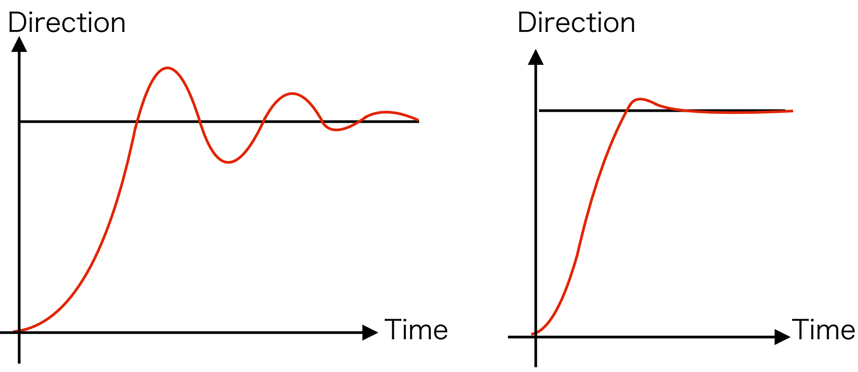


Fig.24 Approximating $\tan^{-1}$ into proportional calculat

3.2 Control



(a) Proportional control(P control) **(b)** PD control

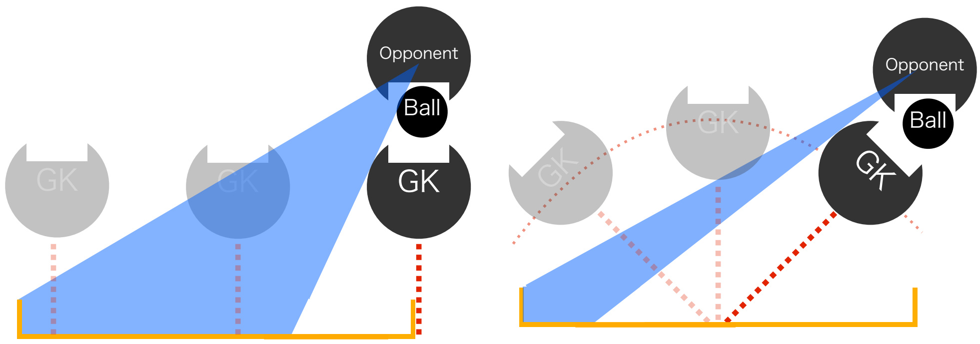
Fig.25 P control and PD control

We would often use proportional control based on the direction data from gyro sensor. But if you use proportional control, it takes a long time to decide the direction. Then, we introduced PD control that uses both direction data and angular velocity data. It enables the robot to decide direction quickly and. stably. This control is based on calculated value by below equation.

"F = a*(direction value)+b(angular velocity value)"

※a,b is defined as coefficient

3.3 Goalkeeper program



(a) General strategy **(b)** Developed strategy

Fig.26 The strategy of goal keeper

The Keeper robot works with its back toward the goal(Fig.26). It detects direction and distance to the goal by using a camera. The x data from the camera shows the direction to the goal. And, the height data shows the distance from the goal(Fig.27). These data enables our robot to defend the goal well.

Fig.27 The detection of the goal

Conclusions and Future Work:

1.1 What we learned

Through RoboCupJunior, I was able to learn a lot of robotics skills.
However, that is not all that I gained. By participating in the competition, I met a lot of people and received a lot of stimulation. Also, making a robot is not an easy task. Therefore, I was able to cultivate a spirit of never giving up, failing over and over again, and rebuilding the robot over and over again.

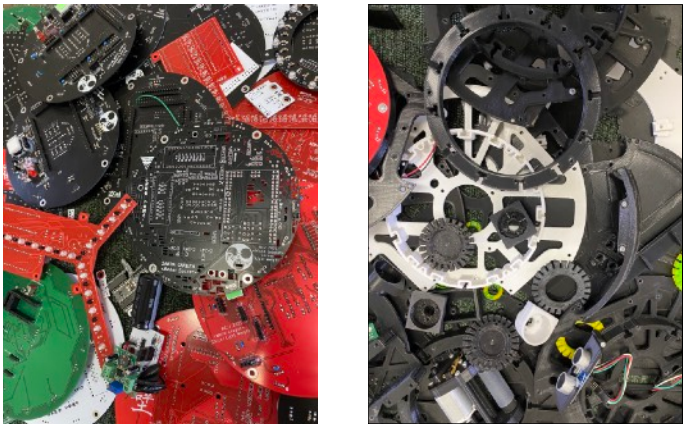
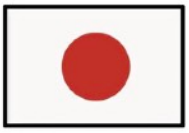


Fig.28 a lot of failed parts

Fig.29 Physics Club



We were able to experience the difficulty and fun of working together as a team to build something. Through RoboCupJunior, we were able to have an invaluable experience.
Thank you very much for RoboCupJunior.

1.2 What we would like to try in the future

Ryotaro Nishi: In the future, I would like to become a bureaucrat and create an environment that facilitates research and development by developing policies and laws. Since I am participating in RoboCupJunior, I know what is needed for technology development.

Sugimori Keita: I hope to use the many experiences I have had at RCJ in the future. At university, I want to do research on robots and eventually create robots that are useful to people.

Minami Kota: I learned the joys, difficulties and responsibilities of teaching during my six years in the club.
I want to use this experience to become a great teacher!

Kenichi Taito: I would like to be a mechanical designer.Through making robots,I could learn a lot about mechanical design, and I found it very interesting.I want to make a useful machine for people.

1.3 A list of resources

http://rcjskycrew.livedoor.blog/
http://gcraud.blog.jp/
http://rcjinput.blog.jp/
http://catbot.blog.jp/
http://blog.livedoor.jp/nakajin0602/
https://www.bbled.org/index.php/lecture1/
https://tomixrm.wordpress.com/tag/rcj/