Research on an Ideal Blade and Torque for *Robot-Sumo*

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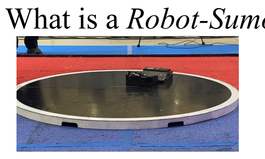
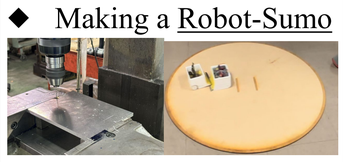
Question

◆ What is a *Robot-Sumo*?



It is a robotics competition that simulates the Japanese wrestling sport, *Sumo*. A robot wins when it pushes the opponent down or to outside the fighting area.

◆ Making a Robot-Sumo



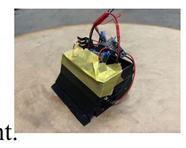
To make a strong robot, we thought that the torque and the blade were particularly important.

◆ Our Hypothesis

There is a relationship between torque and blade, and there is an ideal blade and torque for a strong *robot-sumo*.

Framework

◆ Making the robots



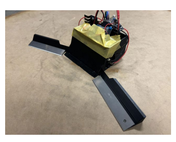
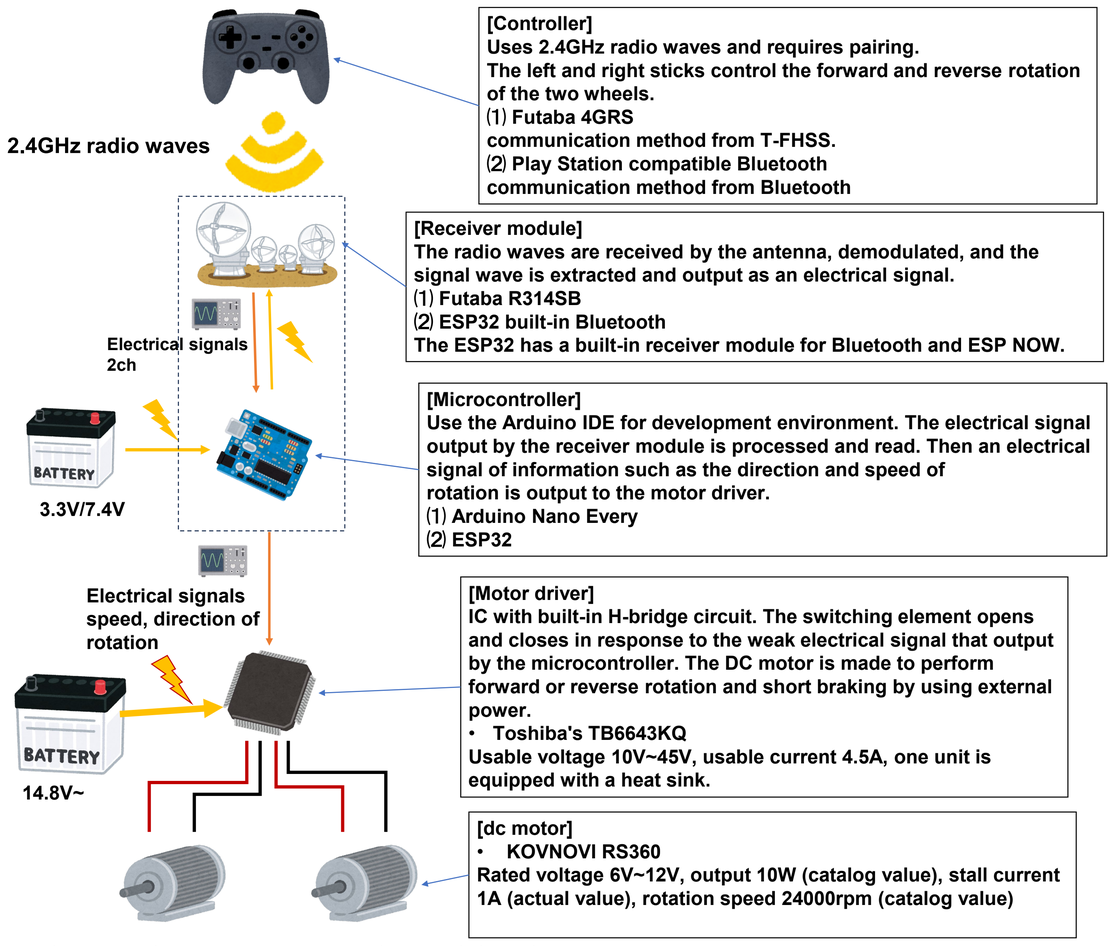


Table 1 shows the types of robots we made. We also made an opponent robot C', which has the same combinations as C, but can only move straight.

Table 1 Combinations of gear ratios and type of blades

Type of blades \ Gear ratios	4.67	42	81	126
Fixed blade	Robot A	Robot B	Robot C	Robot D
Arm type blade	Robot E	Robot F	Robot G	Robot H

◆ How to connect and control the robot



[Controller]
Uses 2.4GHz radio waves and requires pairing.
The left and right sticks control the forward and reverse rotation of the two wheels.
(1) Futaba 4GRS communication method from T-FHSS.
(2) Play Station compatible Bluetooth communication method from Bluetooth

[Receiver module]
The radio waves are received by the antenna, demodulated, and the signal wave is extracted and output as an electrical signal.
(1) Futaba R314SB
(2) ESP32 built-in Bluetooth
The ESP32 has a built-in receiver module for Bluetooth and ESP NOW.

[Microcontroller]
Use the Arduino IDE for development environment. The electrical signal output by the receiver module is processed and read. Then an electrical signal of information such as the direction and speed of rotation is output to the motor driver.
(1) Arduino Nano Every
(2) ESP32

[Motor driver]
IC with built-in H-bridge circuit. The switching element opens and closes in response to the weak electrical signal that output by the microcontroller. The DC motor is made to perform forward or reverse rotation and short braking by using external power.
- **Toshiba's TB6643KQ**

Usable voltage 10V~45V, usable current 4.5A, one unit is equipped with a heat sink.

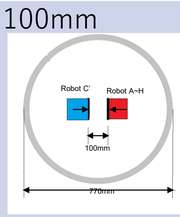
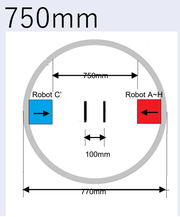
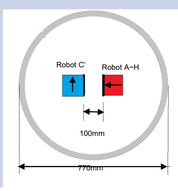
[dc motor]
- **KOVNOVI RS360**

Rated voltage 6V~12V, output 10W (catalog value), stall current 1A (actual value), rotation speed 24000rpm (catalog value)

Figure 1 The way to connect and control the robot

◆ Experiment

Table 2 Components of the experiment

	Distance	Points to record	Process
(1)-1 Pushing each other from the front from close range	100mm 	• Did type A~H push the opponent out? • Time to push out • How it pushed • Which got under the blade of robot	Start at the same time and move forward to push each other.
(1)-2 Pushing each other from the front from far range	750mm 		
(2) Pushing opponent from the side	100mm 	• Time to push out • How it pushed • Which got under the blade of robot	Opponent is placed to the side, and the tested robot moves straight to push out.

Findings

Table 3 Torque of the robots

Gear ratios	4.67	42	81	126
Torque	8.1mNm	73.7mNm	142.2mNm	221.2mNm

◆ The result of experiments

Table 4 Result of experiment (1)-1 : from close range

Type of robot	Result of fight	Place of blade	Time (seconds)	Description of movement	Type of robot	Result of fight	Place of blade	Time (seconds)	Description of movement
A	Draw	Up		"A" pushed opponent little by little, but opponent did not go out of the area.	E	Draw	Down		"E" was immediately pushed down by the opponent.
	Draw	Up				Lose	Down	2.34	
	Draw	Down				Lose	Down	2.27	
B	Win	Down	1.36	"B" flipped opponent over, but was pushed down.	F	Draw	Down		"F" and opponent pushed each other at middle.
	Draw	Up				Draw	**Down**		
	Draw	Up				Draw	**Down**		
C	Draw	Up		"C" and opponent pushed each other at middle.	G	Lose	**Down**	2.58	When "G" lost, it was pushed down. When "G" won, it flipped the opponent over.
	Draw	Up				Win	**Down**	1.83	
	Draw	Down				Lose	**Down**	2.59	
D	Draw	Up		"D" and opponent pushed each other at middle.	H	Draw	**Down**		"H" pushed opponent little by little, but opponent did not go out of the area.
	Draw	Up				Lose	**Down**	5.76	
	Draw	Down				Draw	**Down**		

Table 5 Result of experiment (1)-2 : from far range

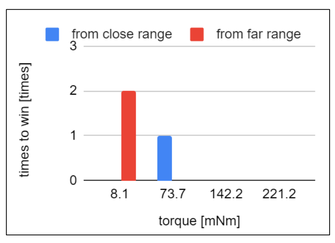
Type of robot	Result of fight	Place of blade	Time (seconds)	Description of movement	Type of robot	Result of fight	Place of blade	Time (seconds)	Description of movement
A	Win	Down	0.93	They hit at opponent area and "A" immediately pushed opponent down.	E	Lose	Down	8.32	When "E" won, it immediately pushed opponent down. When it lost, both pushed each other.
	Draw	Down				Win	Down	1.03	
	Win	Down	0.63			Win	Down	0.99	
B	Draw	Down		They hit at the middle, "B" pushed opponent, then both pushed each other at the middle.	F	Lose	Down	5.08	"F" was pushed little by little by opponent and was pushed out from the area.
	Draw	Up				Lose	**Down**	5.65	
	Draw	Down				Draw	**Down**		
C	Draw	Same		Both pushed each other at middle.	G	Lose	Down	3.73	"G" was pushed out from the area.
	Draw	Up				Lose	Down	2.73	
	Draw	Up				Lose	Down	2.89	
D	Draw	Same		They hit at "D"'s area. Both pushed each other there.	H	Lose	Down	4.50	"H" was pushed out from the area.
	Draw	Down				Lose	Down	2.68	
	Draw	Down				Lose	Down	2.89	

Table 6 Result of experiment (2) *time is the average of three trials

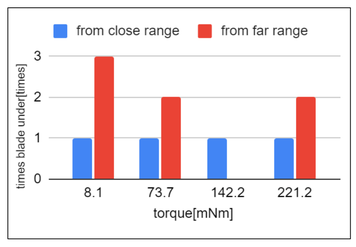
Robot	Time to hit	Time to push out	Robot	Time to hit	Time to push out
A	0.20	0.99	E	0.19	0.49
B	0.23	1.04	F	0.22	1.2
C	0.35	2.75	G	0.33	2.32
D	0.40	3.97	H	0.55	2.60

◆Graphs of the result of the experiments

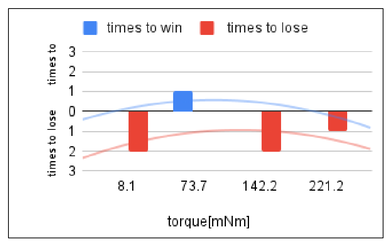
Graph 1 Torque and number of wins using fixed blade (experiment (1))



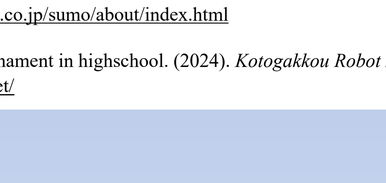
Graph 2 Torque and number of times the blade is under the opponent using fixed blade (experiment (1))



Graph 3 Torque and number of wins and losses, for close range using arm type blade (experiment (1)-1)



Graph 4 Torque and number of wins and losses, for far range using arm type blade (experiment (1)-2)



Graph 5 Torque and time (experiment (2))

Interpretation and Conclusion

Graphs 1 and 2 indicate that larger the torque, the number of wins and the number of times the blade is under the opponent, are on a downward trend. This means that it is better for the fixed blade to have a small torque.

On the other hand, there are different trends for arm type blade for close range and far range. Graphs 3 and 4 indicate that it is better to have a torque around 73.7mNm to 142.2mNm for close range. However, it is better to have a small torque for far range.

From this experiment, we found the following two points that we had not expected.
(1) Regardless of the type of blade, high torque is not good for pushing out. It is because the frictional force of the tire becomes smaller than the pushing force of the high torque robot, and the robot spins freely.
(2) The winning rate of the arm type blade is lower than fixed blade. We think the reason is that the arm type blade has greater running resistance, which reduces its energy to push the other robot.
In the future, we would like to do further research on these points.

Reference

[1] Fujisoft Incorporated. (2024). *Robot Sumo ni tsuite.* ALL JAPAN ROBOT-SUMO TOURNAMENT(online), Search on September 15, 2024 from https://www.fsi.co.jp/sumo/about/index.html

[2] Robot-sumo tournament in highschool. (2024). *Kotogakkou Robot Sumo Senshuken 2024* (online), Search on September 15, 2024 from https://robot-sumo.net/