Universalization of Boccia Ramps Through Motorization - Application of Assistive Technology to Adapted Sports -

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Abstract

In the recent years, interest in adapted sports has been growing worldwide. Among them, Boccia is one of the most popular sports that can be enjoyed by all generations, from children to the elderly, as well as people with disabilities(1). However bedridden people couldn't participate this sport, due to the lack of assistive devices. In this study, we designed and developed a Boccia device which motorizes the normal Boccia ramps so that more people could enjoy Boccia competitions. The device has three elements: "Release mechanism", "Release height control mechanism", and "Azimuth control mechanism". Considering the widespread use of the device, we designed and developed a prototype by simplifying and generalizing the device. After development, we demonstrated the device at three events, and conducted questionnaires to obtain user feedbacks. The results showed that not only people with disabilities but also children and adults tended to enjoy Boccia competitions with this device. This paper reports on this universalized Boccia device.

Keywords: Boccia Ramp, Sports for Disabled Persons, Remote Control, Assistive Technology

1. Introduction

Originating in Europe, Boccia is a sport designed for people with severe cerebral paralysis and those with similar severe limb dysfunctions, and it is an official Paralympic sport. The ball used in the game can be kicked as well as thrown. In addition, the ball can be rolled using a slope device called a ramp. Therefore, the same sport can be enjoyed not only by people with disabilities, but also by children and the elderly people. Boccia is a sport in which more people could participate, regardless of the disability and will contribute to the realization of a symbiotic society as promoted by the United Nations.

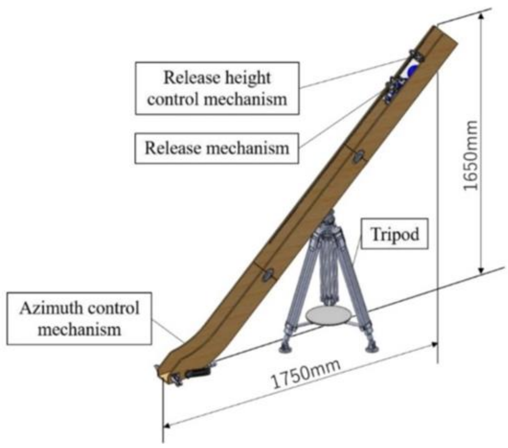


Fig. 1. 3D model of motorized Boccia ramp.

However, according to the official rules of Boccia, the release of the ball must be done by using one's own residual functions. Therefore, bedridden disabled people such as those with amyotrophic lateral sclerosis (ALS) or muscular dystrophy cannot participate in Boccia. Therefore, we have developed a motorized ramp with the aim of enabling more people to participate in Boccia competitions as a previous study (2). The device could be remotely operated by using a controller, a computer, or an eye-control device.

Figure.1 shows the first engineering model of the motorized Boccia ramp. This ramp was specially designed with "Release mechanism", "Release height control mechanism and "Azimuth control mechanism" which were built into the ramp. The motors for each mechanism were wired to a dedicated control box called a multi-box. The ramp could be operated by connecting the multi-box to a PC via USB, which could then be operated it remotely via an Internet connection. This prototype device was studied in cooperation with Unicorn Corporation[3]. Unicorn Corporation is a leading developer of Japanese language eye input support software.

As a result of the previous studies, we obtained two patents in Japan[4][5]. The patents are on an eye-control and a network technology for the ramp and make it possible for a bedridden person to participate in a Boccia game remotely with the control technology.

The first product is larger than conventional ramp, and its wiring is a bit complicated, hence the installing and handling are difficult for the users. In addition, the price of the device was high because it was specially designed for this purpose, making it difficult for the device to be widely used.

The purpose of this study was to develop a device that could be attached to the conventional ramps and to turn normal ramps into assistive devices. This goal setting is based on the following two assumptions. The first assumption was that if we could develop a device which attached on the existing ramps to motorize the Boccia, it would be easy to set up. In addition, we thought that the introduction cost would be lower, and thus we would be able to deliver support to more people.

The second hypothesis is that with the spread of Boccia device, Boccia players (BC3 players) who have never operated the ramps before would be able to do so by themselves. We thought that this would increase the degree of freedom in their practices and reduce the workload on their assistants.

Considering the widespread use of the Boccia device, we designed and developed a universalized prototype by simplifying and generalizing the previous motorized ramp. To evaluate the Boccia device, we demonstrated the device at three events and conducted a survey for its users.

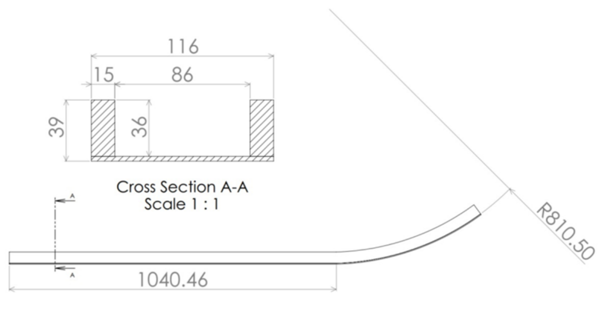


Fig. 2. The dimensions of the relevant ramp.

2. Concept of Boccia Device

There were three design concepts in this study: (1) general-purpose design, (2) use of a simple mechanism, and (3) use of readily available materials.

The general-purpose design was a design that could be used by simply attaching it to any existing ramp without any modification. The use of a simple mechanism was to reduce the difficulty of setting up and to reduce the number of mechanical accidents that may occur due to lack of understanding of the mechanism which involves driving parts which could lead to destruction. The use of readily available materials was to ensure safety and to reduce the cost of production for future widespread use.

There are many types of ramps used in competitions, and it is difficult to survey all of them. For this reason, we conducted a dimensional design assuming the dimensions of the demonstration Boccia ramps owned by the Yamaguchi Prefecture Boccia Association to be representative values. This ramp was common and reasonably priced one sold in Japan. The dimensions of the relevant ramp are shown in the figure 2.

3. Design and Materials of the Device

3.1 Overview

The four main components we fabricated were the (1) "Release mechanism device", (2) "Release height control mechanism device", (3) "Azimuth control mechanism device", and the (4) controller and control box. The design of the three devices were done on 3D CAD (Solidworks 2016 x64 Edition). The controller was made by modifying an existing product. The main materials used for the three mechanisms, the corresponding processing methods, and product information are shown in the figures and tables that follow.

The release mechanism and the release height control mechanism were mainly composed of acrylic sheets and 3d printed parts. Acrylic was used for the base parts because it was easy to process with a laser cutting machine and is stronger than wood. Solvent-based adhesives were used to bond the acrylics parts together. The parts with complex shapes were made using a 3D printer. The use of acrylic and a 3D printer made it possible to quickly fabricate the parts. The azimuth control mechanism and the base table were made from painted plywood because they needed to be strong enough. These panels were cut using a large laser cutting machine. The motors that move the mechanism require a great deal of power, so large motors used for robots were used.

3.2 Release Mechanism

The 3D image of the Release mechanism device is shown in Figure 3 and its materials are also shown in Table 1, respectively.

Release mechanism device was suspended by a ball chain which moved up and down along the slope by the Release height control device. The key parts of this mechanism were a release motor and an electric circuit. Two release arms were connected to both sides of the release motor shaft which pushes up the ball after receiving the release signal. Then the ball overcomes the ball stopper and start rolling down the slope of the ramp. Since transferring the release signal through an electrical cord could cause danger and technical problems in the way of release height control mechanism, this release signal is transferred by Infrared communication. It means that this mechanism needs to work without any external power supply, so this part has a 3V battery box, consisting of 3 AA batteries. The IR-receiver and motor driver circuit was attached on the top side, because the signal is received from the upside. This circuit has motor driving function and IR-receiving function, so it could rotate the motor for a certain period, when an IR signal was received.

This mechanism part has 4 wheels at each corner for smooth moving. This body part has been bent twice to make camera mount space for eye gaze controlling. The camera mount space is set parallel to the ground.

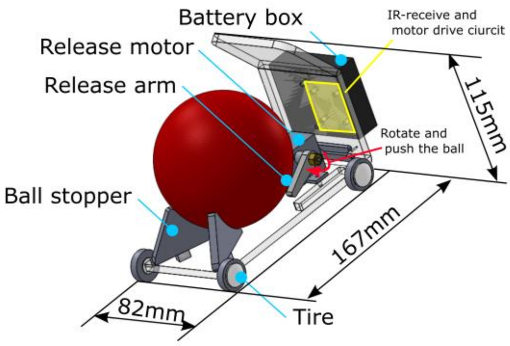


Fig. 3. Image of the Release mechanism device.

Table 1. Materials and Processing Methods of the Release mechanism device

Materials	Method (processing device) / product information
Acrylic 5mm	Laser cutting (Hajime CL1 PLUS: by Oh laser)
	Bending (Pipe shape Heater: Original)
	Taping
PLA (3D-Print material)	3D printing (Replicator 2X: by Maker-bot)
Mini motor low-speed gearbox	Item No. 70189: by Tamiya
Electrical circuit	Dot Board PCB Size 4×3 Inches 10×7.5 cm dotted
Infrared receiver	VS1838B: by Photoelectricity
3v relay	Y14H-1C-3DS: by HSIN DA PRECISION CO. LTD

3.3 Release Height Control Mechanism

The 3D image of the Release height control mechanism device is shown in Figure 4 and its materials is also shown in Table 2, respectively.

The Release height control mechanism device moves

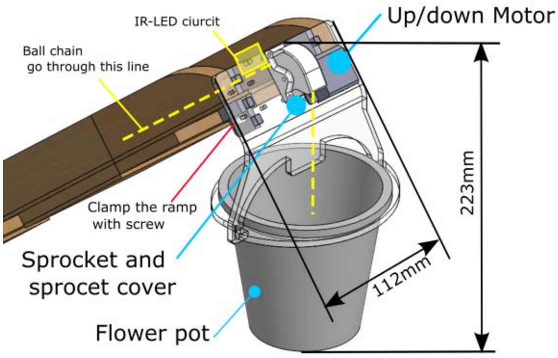


Fig. 4. Image of the Release mechanism device.

Table 2. Materials and Processing Methods of the Release height mechanism device

Materials	Method (processing machine) / product information
Acrylic 5mm	Laser cutting (Hajime CL1 PLUS: by Oh laser)
	Bending (Pipe shape Heater: Original)
	Taping
PLA (3D-Print material)	3D printing (Replicator 2X: by Maker-bot)
Mini motor multi-ratio gearbox	Item No. 70190: by Tamiya
Plastic flower pot	12cm diameter (In Japanese scale 4 gou)
Plastic ball chain	Ball diameter is 4.8mm

the Release mechanism up and down with a ball chain. The key parts of this mechanism are a sprocket for the ball chain and a motor. The ball chain is a string that has plastic balls at constant distance gap and normally used for roller blind. Since the balls get caught by the holes of the sprocket, this chain is difficult to slip, so it is good at pulling up and down a light object. One end of the string is connected to the release mechanism, so when the sprocket rotates, the release mechanism moves up or down. The other end of chain is a free end, therefor a flowerpot is attached right under the sprocket to collect the pulled ball chain. The flowerpot was fixed to the main body with using a ring, similar to a drink holder of found in movie theatre chair. On this part, there is an IR-transmitting LED circuit, which transfers the ball release signal to the release mechanism. This mechanism was fixed on top of the ramps by clamping it with screws.

3.4 Azimuth Control Mechanism

The 3D image of the Azimuth control mechanism device is shown in Figure 5 and its materials are also shown in Table 3, respectively.

The Azimuth control mechanism device is a turning mechanism, and it rotates the ramp in the desired direction. The key parts of this mechanism are the base table and the radial bearing, which is normally used in traditional Chinese restaurant's turn tables. The base table is fixed with a bearing and is rotated by a motor. This motor is attached on top of the small plate. Since this plate was fixed with a hinge to base table, motor could move up and down along the unevenness of the ground to prevent the tire leaving from the floor. To reduce the processes of assembly and disassembly, ramp's leg is firmly fixed on to the board.

To operate these mechanisms, PC and controller could be used. Therefore, this ramp could be operated with any kinds of assistive switch or input devices, such us eye-gaze control and touch sensor switches, by modifying the connections between switches and the PC or the controller. To control from the PC, this ramp has a "Miyasuku multi-box". This is a USB switching device and which was developed by Unicorn to operate home appliances from its eye-gage PC software "Miyasuku series". A block diagram of controlling a lamp from a PC using the multi-box is shown in Figure 6.

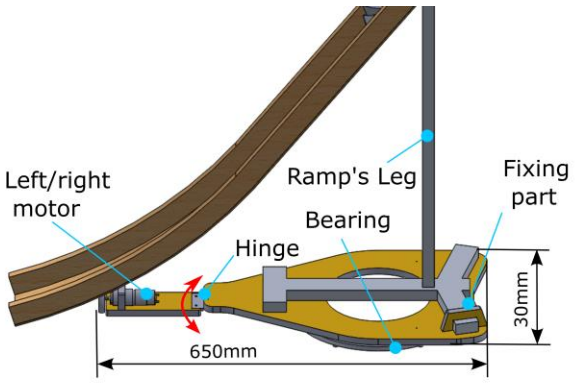


Fig. 5. Image of the Azimuth mechanism device.

Table 3. Materials and Processing Methods of the Azimuth mechanism device

Materials	Method (processing machine) / product information
Painted plywood panel	Laser cutting (SILAS SPL3830: by Shibuya Industrial)
Geared Motor	MS-385PH-2465: by Mabuchi motor
Bearing	30cm Diameter
Hinge	Hinge for door, size 51mm*34mm

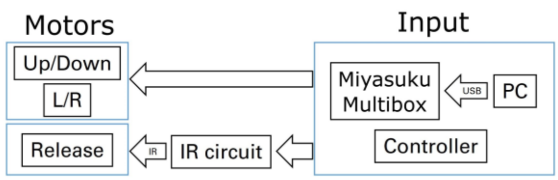


Fig. 6. Block diagram of ramp control from PC

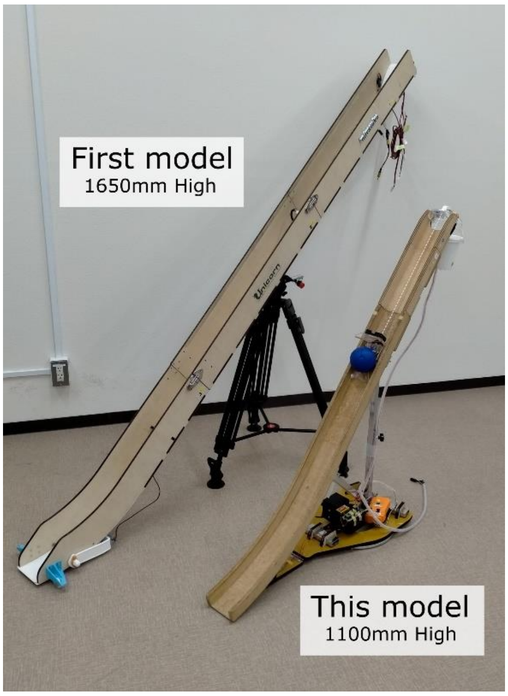
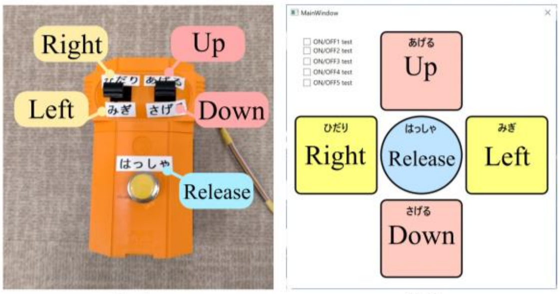


Fig. 7. Image of the Boccia device.

4. Method of Experiment and Questionnaire

Boccia devices developed in this study and previous study is shown in Figure 7. To operate the device, a controller was attached to the multi-box. The controller is a simple commercially available controller with pushbuttons attached. Each switch on the controller was assigned the role of up/down, left/right, and release(throw). The controller and the computer operating screen are shown in Figure 8(a) and Figure 8(b), respectively.



(a) (b)

Fig. 8. Screenshot of (a)Controller and (b)Computer operating screen.

At present, there is no clear indicator for the performance of Boccia ramp devices. In this study, we presented three performance indicators: vertical movement speed, left-right movement speed, and the maximum distance that can be thrown. For vertical movement speed, we recorded the time it took to climb up and down 50 cm in the central area of the ramp and calculated the up/down speed from an average of five times. The rotation speed in the left-right direction was determined by recording the time to rotate 90 degrees five times in each direction, and the rotation speed was calculated from the average of 10 times. The maximum distance that can be thrown was determined as the straight-line distance from the center of the top of the ramp when the Release mechanism was installed at the highest point of the ramp and the throw was made by the Release motor. These measurements were done 8 times on a smooth floor (college hallway).

On the other hand, to examine the functionality and the usability of the completed Boccia device, we exhibited it at three public events. The main target of each exhibition were children. We used demonstrations to confirm that the Boccia device could be used in competitions. We also conducted a questionnaire survey to see how participants felt about using the system and whether they thought it was simple or not.

In the demonstrations, we first taught the participants how to operate the system. After that, the participants were asked to use the controller and the PC, at the end of the demonstration, we asked the participants to fill out a questionnaire. The answers to the questions were selected from a five-point scale between Yes and No. The questions in the questionnaire are shown below:

(1) Is Boccia fun?
(2) Do you think it's a simple system?
(3) Do you think you can assemble it?
(4) Other Comments.

5. Results And Discussion

Performance data of Boccia device obtained from the experiment are shown in Table 4. The experiment revealed that the ascent speed was 90 mm/s, the descent speed was 120 mm/s, the azimuth rotation speed was 12 deg./s, the throwing distance was 7.7m, and the weight was 6.5 kg. Here, each speed represents the average of five times. Each speed is sufficient for the competition to proceed smoothly.

Table 4. Performance data of the Boccia device

Performances	Specs
Climbing speed	90mm/s
Lowering speed	120mm/s
Azimuth rotating speed	12deg/s (7.5s per 90deg)
Throwing distance at the highest point	7.7m
Gross weight	6.5kg

The weight of the present model when extended to the height of the first model was estimated to be 7.6 kg. The weight of the first model is 11.8 kg. Therefore, this model weighs 4.2 kg less than the first model. The wiring was one of the elements that users found difficult, which was made easier by the use of stereo jacks. Therefore, installation of the device could now be done within about five minutes.

Meanwhile, the demonstrations of the Boccia device is shown in Table 5. The details of the three events where we exhibited are shown in the table below. We could not count the number of participants properly, so the numbers were an approximate. We were able to obtain 12 questionnaires from the three events. The respondents were mostly parents of the children. The ages of the children ranged from 5 to 12 years.

The results of the questionnaire are summarized in the figure 9. The darkest color is "Yes" and the lightest is "No"

Table 5. Information of the Boccia Device Demonstration

Date	Places	Participants (approximate)
Nov. 21. 2021	Koshi SWC, Koshi city, Kumamoto	10
Dec. 12. 2021	LooLo Koshi, Koshi city, Kumamoto	20
Dec. 12. 2021	Tokuyama station library, Shunan city, Yamaguchi	10

on a scale of five levels. From the results of the questionnaires, it can be said that Boccia could be enjoyed with the ramp and machine we made. A participant commented, "I thought it was a competition that various people could enjoy together by using a machine”. Another participant commented, "Even a small child with no power could enjoy it”. This indicates that this machine was an effective assistive device for the small children as well. There was also a comment, "They seemed to really enjoy being able to control it by themselves". From these comments, we thought that this machine could be used not only as an assistive device but also as a new way to play Boccia. And then, from the results of questions 2 and 3, which asked about the simplicity of the mechanism, we found that more than half of the respondents felt that the mechanism was difficult.

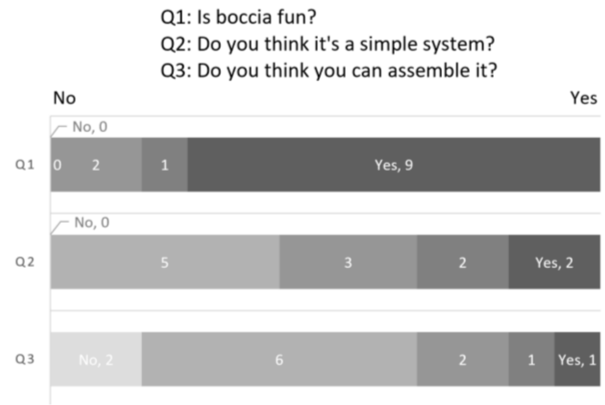


Fig. 9. The bar graph of questionnaire results.

6. Conclusions

We have tackled on the universalization of the Boccia device in order to allow many different people to enjoy Boccia regardless of age or disability. The result of this study shows that this device was able to achieve the same functions as the previous device in a simpler way. This means that a simpler Boccia support device was made in this study. There were no major problems with the mechanical strength and safety, and the device did not break even after multiple assembly and disassembly events. The operation method was also simple, and about half of the participants felt that the mechanism was easy. However, there were some who felt that preparation and creation were difficult. We realized that mechanical elements should be made simpler.

7. Future works

Our goal is to develop an easier system based on the current method in the future. We also plan to demonstrate the system at special needs schools to discover problems that have not yet been found and to make improvements.

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