2021-2022 Design and Manufacturing Ⅰ

VM250

Final report

Project title:

Omni-motion, Bluetooth-remote-control
and Self-reloading Automatic Catapult

Group members:

Xinlei Zhang 202030101256
Jinan Guo 201930031052
Ze`an He 202030020342
Juncong Lan 202030020113
Yile Shen 202030020205

Shien-Ming Wu School of Intelligent Engineering

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Content

Abstract:
This project is mainly designed to be able to finish all the tasks proposed in the requirements—remotely control the catapult to launch different balls in some specific points with automatic reloading. After taking QFD analysis about this project, we divide the whole project into four individual systems: driving, remoting, launching and reloading. Learning from the classical mechanical model and state-of-the-art technology, we design this omni-motion, Bluetooth-remote-control and self-reloading automatic catapult. In this report, we discuss the designing process in detail, from the concept design using QFD method, to the prototypes of different system, experimental results & performance evaluation, discussion about the final product, the cost estimation about the whole procedure and the conclusion on the project. In the end, we also list all the references we cite, the nomenclature used in this report, and the acknowledge of this project. All other related works are attached in the appendix.

Key words: **QFD method, omni-motion, Bluetooth remote, lever-spring catapult, turbine-based reloading.**

I. Introduction

This project is aimed at using the knowledge learned in the course VM250, Design and Manufacturing I, to design a real-world physical system to finish all the given tasks in the given place (figure 1.1), in brief, remotely controlling the system to move to some specific points (the red points) to launch different balls to the target box (the basket) without any human physical contact during the whole process. Thus, this entire system should be designed to be equipped with at least these four basic functions: motion, remote control, launch and reload.

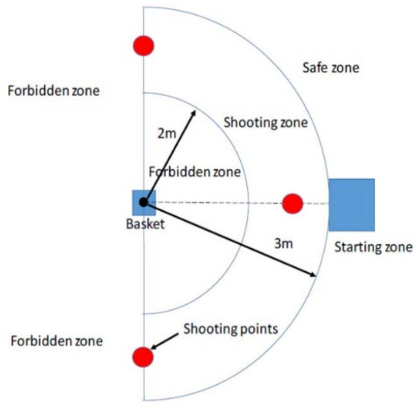


Figure 1.1 The given place

Catapult, as shown in figure 1.2, mechanism for forcefully propelling stones, spears, or other projectiles, in use mainly as a military weapon since ancient times.[1] Fully-mechanical-dependent and stable launch ability make it our first choice for the launching system. Turbine-based device inspires us that we can store all the balls in the cell formed by every two adjacent turbine blades and reload the ball by rotating the turbine, like water is lifted by the traditional hydro turbine in figure 1.3. As shown in figure 1.4, Bluetooth has been a widely-used communication technology and it's installed almost in every cellphone. We can use this stable, low-delay method to realize the remote control on the system by our cellphones. Finally, as a state-of-the-art technology, omni-wheel motion has been applied in industry due to its flexible motion and steering. Figure 1.5 shows an educational product produced by VEX company, which is equipped with four omni wheels in this device. Employing this type of flexible motion, we can easily adjust the orientation of the catapult so as to aim at the target box.

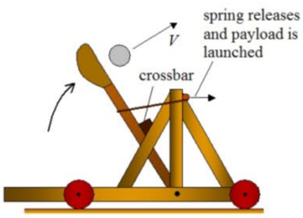


Figure 1.2 Ancient Catapult


Figure 1.3 Hydro Turbine

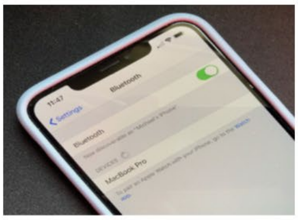


Figure 1.4 Bluetooth in cellphone


Figure 1.5 Omni wheels

II. Concept Design

Based on the understanding of the project's objectives and requirements, we do the concept design according to the procedure below to fulfill the task.

i. Problem Definition

a) Customer Requirements

We have done a brainstorm in design group on our own experiences from eight basic dimensions of quality which are performance, features, reliability, durability, serviceability, conformance, aesthetics and perceived quality. After that, we classify these requirements into four categories as shown in Table 2.1.1 bellows.

Table 2.1.1 Customer Requirements

Customer Requirements			
Expecters	1.remote controlling	Unspokens	11.simpler operation
	2.launch function		12.higher stability
	3.self-reloading		13.precise adjustment
	4.bigger carrying capacity		14.neaty arrangement of dupont lines
	5.wider adaptability		15.more durable
Spokens	6.more flexible motion	Exciters	15.exquisite appearance
	7.higher precision		16.automatic aiming
	8.higher accuracy		17.higher degree of automation
	9.lower cost		18.Innovative design
	10.higher efficiency		
Annotation:			
1)	Expecters: standard features/basic attributes		
2)	Spokens: specific features helpful to finish the task better (obvious)		
3)	Unspokens: specific features helpful to finish the task better (unobvious)		
4)	Exciters: features that make the product unique and distinguish		

b) Engineering Characteristic

We also generate the engineering characteristics in three aspects, Design parameters, Design variable and Constraints, in Table 2.1.2.

Table 2.1.2 Engineering Characteristics

Engineering Characteristics			
Design parameters	1.launch range: around2.5m	Constraints	13.size limit: 35x20x35cm
	2.precision range: 20x20x20cm		14.finished time: <=10min
	3.launching adaptability		15.using remote controller
	4.storage capacity		16,only shoot one ball at a time
	5.reloading adaptability		
	6.positional accuracy: around 5cm		
	7.directional accuracy: around 0.02°	Annotations:	
Design variable	8.wheel type	1) Design parameters: physical properties	
	9.motion mode	for design form and behavior determination	
	10.launch power source	2) Design variable: the choice of prototype	
	11.launch device structure	3) Constraints: limits on design freedom	
	12.aiming and ranging module		

c) QFD Analysis — House of Quality

We use quality function deployment to translate the important customer needs into critical-to-quality engineering characteristics. The house of quality is shown below.

Table 2.1.3 House of Quality

		Engineering characteristic								
Improvement direction		↑	↓	↑	↑	↑	n/a	n/a	n/a	↓
Customer Requirements	Importance weight factor	launch range	precision range	storage capacity	positional accuracy	directional accuracy	wheel type	motion mode	aiming and ranging module	finished time
bigger carrying capacity	3			9						9
more flexible motion	4	3			9	3	9	9		9
higher precision	5		9							
higher accuracy	5	1			9	9		3	3	
lower cost	2	1		1			3		1	
higher efficiency	3						3	3	1	9
simpler operation	4	1	9	3			9	3	9	1
higher stability	5				3	3		3		1
precise adjustment	5	1			9	9	9	9	3	3
higher degree of automation	3			9					3	3
Raw score		28	81	68	141	117	132	132	80	133
Relative weight%		3.1	8.9	7.5	15.5	12.8	14.5	14.5	8.8	14.6
Rank order		9	6	8	1	5	3	3	7	2

From the table, we can find out that the positional and directional accuracy, finish time (which is related to the total efficiency), wheel type, motion mode and the precision range are the six most critical aspects to the success of the project, which should be the focus in the following idea generation and concept selection.

d) Product Design Specification

Table 2.1.4 Product Design Specification

Product design specification

Product Identification

- Omni-motion, Remote-control and Self-reloading Catapult
- Function:
  - Omni-motion
  - Remote control
  - Balls storing
  - Balls shooting
  - Self-reloading
  - Steering
  - Adaptable to 3 kinds of balls
- Special features:
  - Collimation
  - Laser ranging
- Key performance targets:
  - Launch range: 2.5m±0.1m
  - Target range: 20x20x20cm
  - Flexible steering
  - Precise braking
  - Simple operation
  - High stability

Key project deadlines

- Project report: 29th May
- Project: 10th June

ii. Information Gathering

a) Research Articles

We've done the literature review given some relevant key words, like omni-motion wheel, lever-spring catapult, and Bluetooth control, through Google Scholar, Semantic Scholar and The Web of Science. All the cited references are listed in VII. Reference.

b) Consultants

From an interview with senior students, we have drawn a conclusion that compared with friction wheel, catapult exhibited greater stability and got better grades in the last year's competition.

iii. Idea Generation

a) Functional Models

After discussion, we divide the whole project into these five basic functional parts, as shown in Table 2.3.1.

Table 2.3.1 Five Functional Models

Functional Model	Motion	Shooting	Reloading	Remote Controlling	Aiming and Ranging

b) Brainstorming

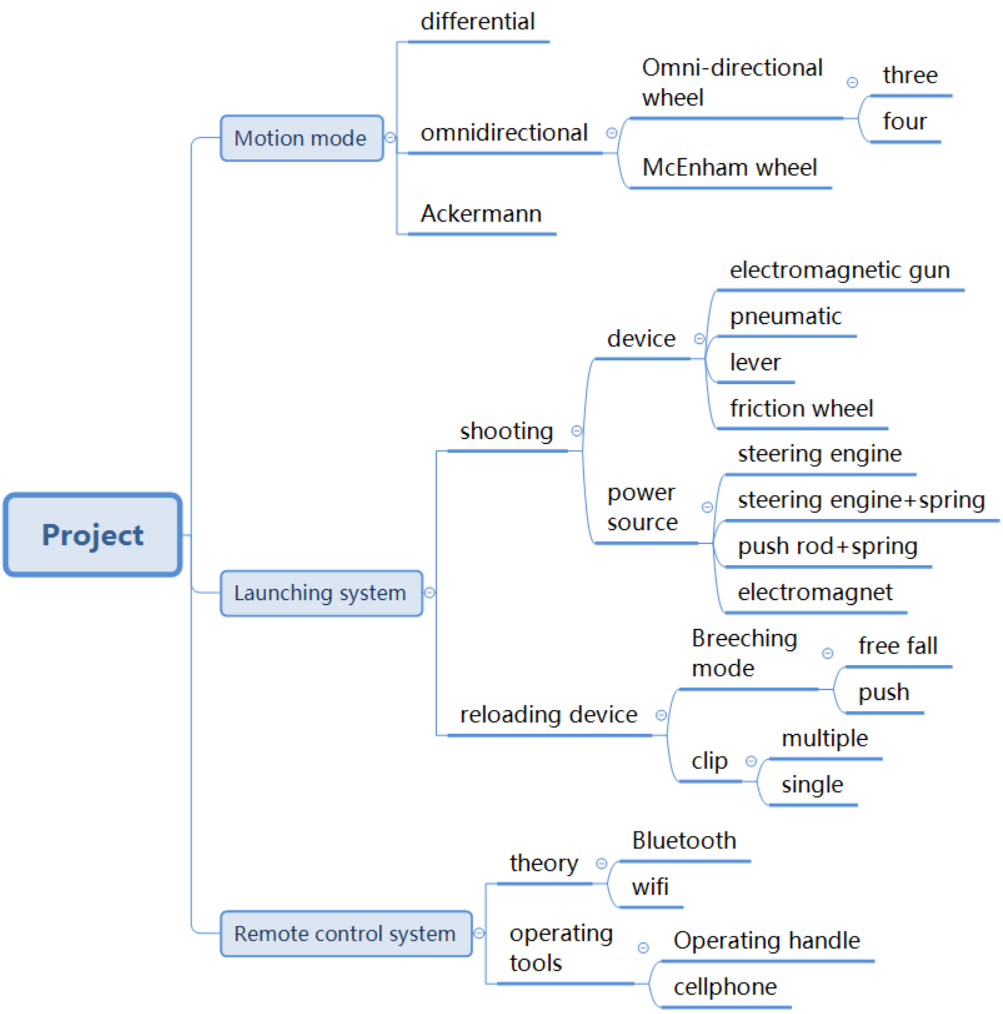


Figure 2.3.2 Mind Map of Idea Generation after Brainstorming

iv. Concept Evaluation and selection

After brainstorming, there are plenty of ideas we can select in different systems. To make the final decision scientifically appropriate, we set different selection criteria for different systems and conduct the analytic hierarchy process. All these criteria are agreed upon by at least four people, 80% of our team members. Then, we also formulate decision matrixes to make every important choice.

a) Selection Criteria and Analytic Hierarchy Process

Importance Ranking	1	2	3	4	5	6
Motion Mode	Flexibility	Fine-tuning	Efficiency	Stability		
Wheel	Flexibility	Size (small)	Easy to install	Friction Coefficient	Wear-resisting	Price-friendly
Launching	Adjustability	Degree of controlling	Stability	Adaptability	Energy consumption (low)	
Reloading	Degree of automation	Capacity	Wide adaptability	Efficiency		
Remote Controller	User-friendly	Degree of customization	Multi-functional			
Aiming and Ranging	Range (suitable)	Accurate	Precision (high)			

Table 2.4.1 The Selection Criteria of ideas for different functional modes

b) Decision Matrix

Table 2.4.2~2.4.5 Decision Matrixes for different important choices

motion mode					
factor	flexibility	fine-tuning	efficiency	stability	count
weight	4	3	2	1	
differential	2	2	4	4	26
omnidirectional	5	5	3	4	45
ackermann	4	2	4	4	34

Table 2.4.2

wheels				
factor	flexibility	size	price-friendly	count
weight	3	2	1	
common wheel	1	2	3	10
Mecanum Wheel	3	3	1	16
omni-directional wheel	3	3	2	17

Table 2.4.3

shooting device						
factor	adjustability	degree of controlling	stability	adaptability	energy consumption	count
weight	5	4	3	2	1	
catapult	3	3	4	5	5	54
friction wheel	3	3	2	3	1	40
electromagnetic gun	3	3	2	3	3	42

Table 2.4.4

remote control - operating tools				
factor	user-friendly	degree of customization	multi-functional	count
weight	3	2	1	
operating handle	5	2	1	20
cellphone	3	5	5	24

Table 2.4.5

III. Manufacturing

In this section, we take deep insight into these four individual systems, deriving the fundamental working principle behind them and describing all the related issues during manufacturing.

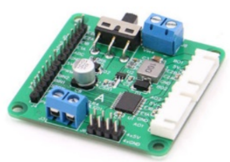
i. Embodiment Design Prototype

a) Driving System

As for the driving system, we employ four orthogonally-arranged omni wheels, which has been proved to possess the greatest net body velocity comparing to any other system with different number of wheels or different mounting angle when the angular velocity of wheels is the same.[2] Besides, we also use the signal harvested by encoders to calculate the actual angular velocity of each wheel and conduct precise control on these angular velocities based on PID algorithm.

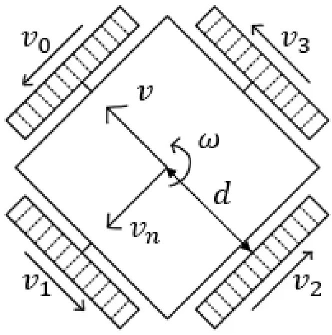
1. Material

Table 3.1.1.1 The material used in driving system

Item	DC Geared Motor	Motor Driver	Omni wheel	Encoder
Type	MG513	TB6612	60mm	Hall Encoder
Picture				
Number	4	2	4	4

2. Kinematic Model

The dynamic model of four omni-wheel based motion has been discussed by H. Oliveira[3]. We only consider its kinematic model in this project because we directly control the angular velocity of each wheel by controlling the PWM value, rather than taking any control on the torque output by the DC geared motor.



- $d[m]$: distance between the center and wheels;
- $v_0, v_1, v_2, v_3 [m/s]$: wheels linear velocity;
- $v, v_n [m/s]$: net body linear velocity;
- $\omega [rad/s]$: net body angular velocity;

Figure 3.1.1.1 Kinematic Diagram

Through the kinematic diagram, as shown in the figure 3.1.1.1, we can obtain the relation between the angular velocity of each wheel and the net body linear and angular velocity,

$$\begin{bmatrix} v_0 \\ v_1 \\ v_2 \\ v_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & d \\ -1 & 0 & d \\ 0 & -1 & d \\ 1 & 0 & d \end{bmatrix} \begin{bmatrix} v \\ v_n \\ \omega \end{bmatrix} \tag{1}$$

Rearranging this equation, we can derive the net body velocities determined by each wheel's linear velocity,

$$\begin{cases} v = \frac{1}{2}(v_3 - v_1) & (2) \\ v_n = \frac{1}{2}(v_0 - v_2) & (3) \\ \omega = \frac{1}{4d}(v_0 + v_1 + v_2 + v_3) & (4) \end{cases}$$

3. Control Strategy

As shown in Figure 3.1.1.2, our driving system can be further divided into two parts, front-end and back-end. In the front-end, we control the voltage output from the motor driver by controlling Arduino Mega2560 to output a specific

PWM value to achieve the regulation of the angular velocity of a wheel.

However, we cannot directly get the angular velocity we want since there is no explicit relation between the PWM value and the final angular velocity. Also, the angular velocity is always fluctuating even though the PWM value we set is constant due to the instability of the PWM output. Thus, we add four encoders to these motors to harvest the actual angular velocity of each wheel and we design a PID controller in the back-end to process the feedback angular velocities, which will adjust the PWM value we set based on its internal calculation, to let the angular velocity converge to the target value.

The logic of the PID controller can be explained by these equations,

$$P_{term} = K_p e(t) \tag{5}$$

$$I_{term} = K_i \int_0^t e(t) d\tau \tag{6}$$

$$D_{term} = K_d \frac{d[e(t)]}{dt} \tag{7}$$

where K_p, K_i, K_d are the constant parameters we set, $e(t)$ is the error term which is equal to the difference between the target angular velocity value and the actual angular velocity value measured by the encoder.

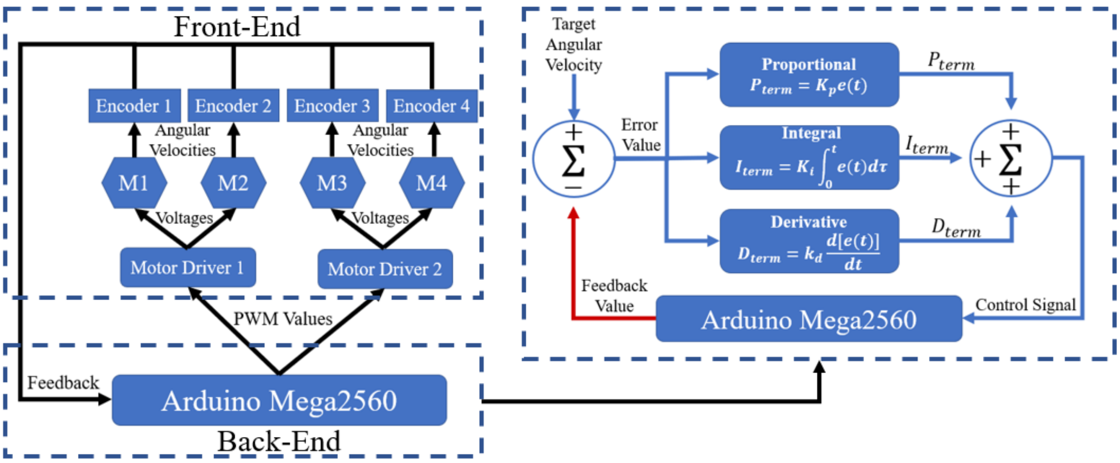


Figure 3.1.1.2 Block Diagram for the Front-End and Back-End of Driving System

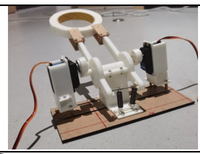
b) Launching System

We designed two versions of launching system during this process. We begin with talking about the material and the working principle of the version I. However, this version is quickly obsoleted after we conduct some experiments because the servos are not powerful enough to turn the lever to the desired angle and launch the ball to the desired position. Then, we continue to talk our version II where we retain most mechanical structure of version I and improve the method we drive the lever.

1. Version I

1) Material

Table 3.1.2.1 The material used in launching system Version I

Item	Servo Motor	Push-Pull Electromagnet	Spring	3D Print Structure
Type	MG995		Appendix IV	Resin
Picture				
Number	2	8	4	

2) Working Principle

The principle of Version I of launching system is that the steering gear of the servo motor and the lever are connected by a push-pull electromagnet (abbreviated as electromagnet). The electromagnet is installed on the disc connected to the steering gear. Its front end will stick out and snap into the groove of the lever, as shown in figure 3.1.2.1. When the steering gear rotates clockwise, it will drive the lever to rotate the same angle in the same direction, stretching the spring at the same time. After the steering gear rotates to the desired angle, energizing the electromagnet. The front end of electromagnet is retracted, making the servo and the lever separate. While the spring is retracted, the lever quickly turns counterclockwise due to the force imposed by the spring, thereby launching the ball at the end of the lever.

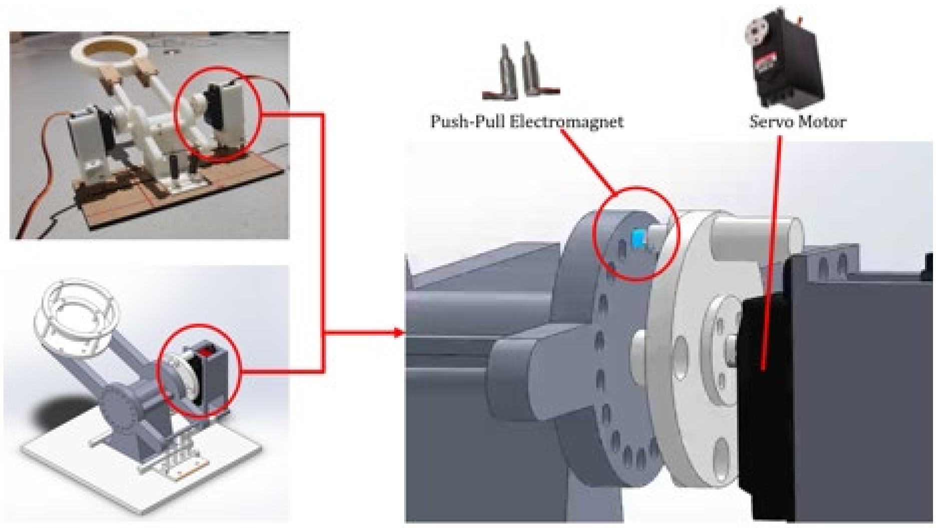
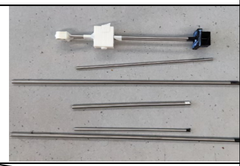
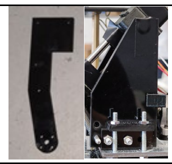


Figure 3.1.2.1 The Detailed view of the lever driving method I

2. Version II

1) Material

Table 3.1.2.2 The material used in launching system Version I

Item	Servo Motor	Stepper Motor + Screw Rod	Spring	Steel Rod	Laser-cutting Structure
Type	MG995	JKM NEMA17 42	Appendix IV	6mm	PMMA 5mm
Picture					
Number	1	1	4		

2) Working Principle

The principle of the Version II of launching system is to fix a hook on the steering gear of the servo motor. The servo is installed on the screw rod. And the stepper motor at the back end is used to drive the screw rod to move the servo forward and backward. Since the length of the hook is fixed, when the servo moves back, the lever will be depressed and the spring at the front end will be stretched. Once the servo moves back to the desired position, the steering gear will rotate the hook to release the lever, and the spring will pull the lever to launch the ball.

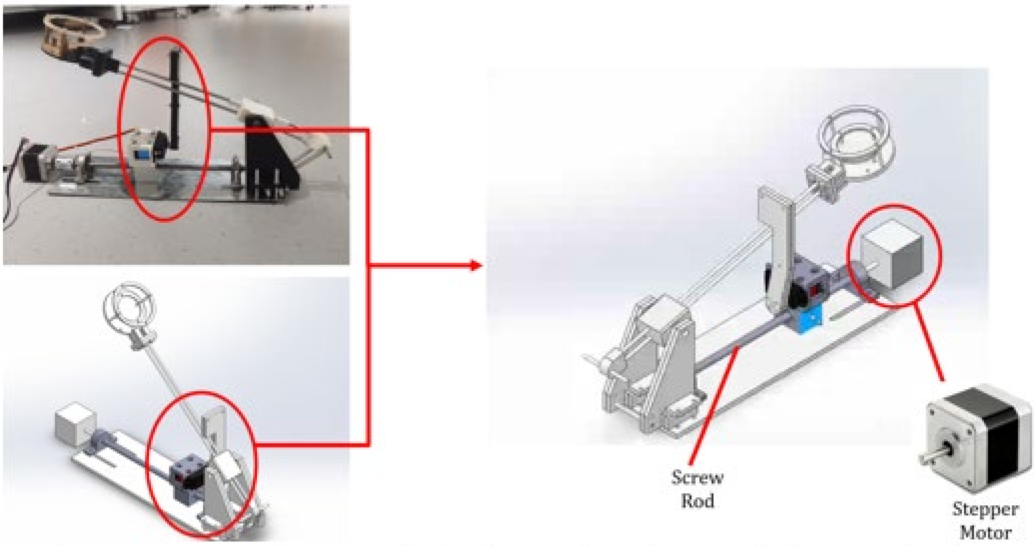
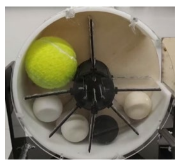
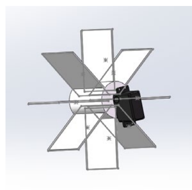


Figure 3.1.2.2 The Detailed view of the lever driving method II

c) Reloading System

1. Material

Table 3.1.3.1 The material used in Reloading system

Item	Servo Motor	Sliding Way	Stepper Motor	Permanent Magnet	3D print Structure	Laser-cutting Structure
Type	MG995	17cm	35BYJ-46	Fe-Ni	Resin	PMMA 2mm
Picture						
Number	1	1	2	14		

2. Reloading Principle

We design a cylinder clip with 98 cm radius which divided into 8 parts averagely by using baffle boards. In the center of the clip, we design a structure to connect baffle boards and the large torque servo motor. The servo motor will rotate and lift the balls in the cell to the exit. The ball will be lifted by the track we design after they leave the exit, which is limited to move in vertical direction by the sliding way. The lifting process is driven by two stepper motors. We use these two stepper motors to rotate a disk which is fixed with the steering shafts of these two stepper motors. The two ends of one string are connected with the disk and the basket respectively. When stepper motors rotate, the ball with the basket will be lifted.

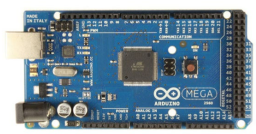
3. Detachable Device

To make the process of reloading efficient, the total reloading device is designed to be detachable, where we use 6 litter permanent magnets, as shown in figure, to connect the clip and lid. Thus, when we need to reload, we can just take off the lid or take the whole clip off. One important point is that lots of acrylic boards are used which means we can repair our model easily.

d) Remoting System

1. Material

Table 3.1.4.1 The material used in remoting system

Item	Bluetooth Server	Bluetooth Client	Signal Processor
Type	HC-06	Cellphone	Arduino Mega2560
Picture			
Number	1	1	1

2. Control Logic

The principle of Remote system is simple. The mobile phone sends the specified signal to HC-06, and HC-06 transmits the signal to the Arduino. According to the received signal, the Arduino executes the corresponding code to control the car to complete the corresponding action. The whole control process is shown is figure 3.1.4.1

The remoting system controls all other systems in the car, including the driving system, the reloading system and the launching system.

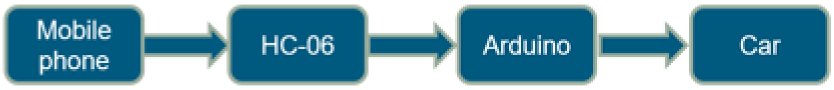


Figure 3.1.4.1 Flow Chart for the Bluetooth Control Logic

1) Driving System

The motion mode of the car is four-wheel omni-wheel motion, which can realize the movement of any angle in any direction and the in-situ rotation of two directions. However, since the Bluetooth app in the client does not have a special rocker to control the movement of the car, we only set the movement in a specific direction, including forward, backward, left, right, left front, right front, left back, right back, eight directions of movement, and clockwise and counterclockwise rotation in place, totally ten movement modes. These motion modes can meet our requirements for the vehicle to reach the designated location and adjust the launch angle.

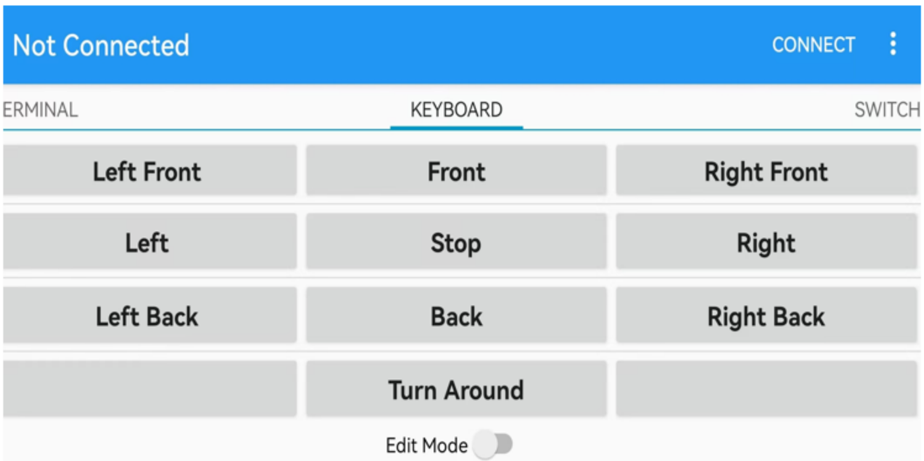


Figure 3.1.4.2 The UI interface of remote motion mode control

2) Launching System

The operation method of the launching system is: at first, move the slider to the last end, the mobile phone sends the command "P" — set this place as the origin, and then press the key '1'; to move the slider to the front end, rotate the hook to hook the lever, and slide back to the origin (shown in figure 3.1.2.3). Then according to the type of the ball we choose to launch, move the slider to the corresponding position, and then press the button 'launch', the ball is thrown.

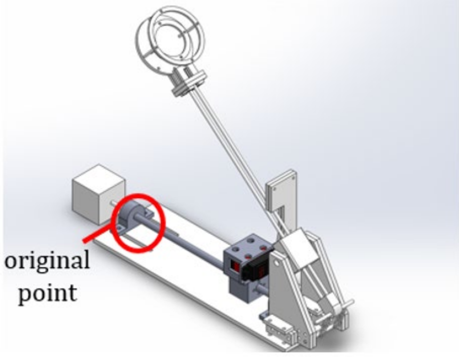


Figure 3.1.4.3 Illustration for the Launching Process

3) Reloading System

The main operation of the reloading system is that the servo motor rotates the baffle plate to drive the ball. The servo motor can rotate at a large angle or a small angle. After the servo motor moves, the stepping motors drive the lifting platform to move up and down so that the ball falls into the launching device.

3. Remote Control Command Table

Table 3.1.4.2 The Command Table

Key	Signal	Function
Front	w	Move front
Back	x	Move back
Left	a	Move left
Right	d	Move right
Left Front	q	Move left front
Right Front	e	Move right front
Left Back	z	Move left back
Right Back	c	Move right back
Stop	s	Stop
1	j	Perform the first step of the launch procedure
2	n	Perform the second step of the launch procedure
Slide forward	l1	The slide moves forward
Slide back	l2	The slide moves back
The slide moves four units	l4	Slide moves to tennis ball launch position
The slide moves	l5	Slide moves to squash launch position

five units		
The slide moves six units	l6	Slide moves to table tennis ball launch position
+30	b1	The servo motor turned counterclockwise at a wide angle to drop the ball into the basket
-30	b2	The servo motor turned clockwise at a wide angle to drop the ball into the basket
+5	b3	The servo motor turned counterclockwise at a small angle to drop the ball into the basket
-5	b4	The servo motor turned clockwise at a small angle to drop the ball into the basket
Launch	y	The hook loosens to throw the ball
Reset	p	Specifies the current position of the slide as the origin point.

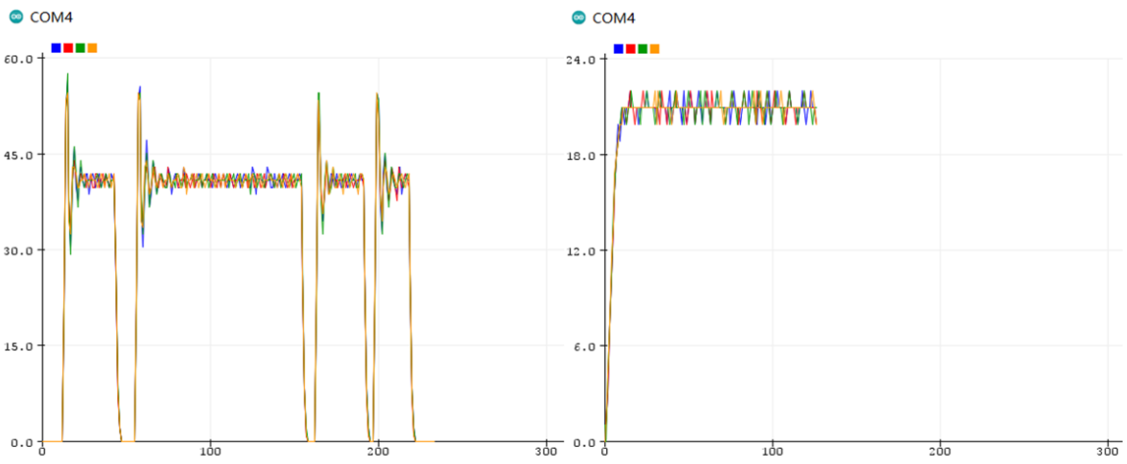
ii. Manufacturing Process

a) Driving System

After experiments, we finally set the same target angular velocity for those ten motion modes. Adjusting the PID parameters, K_p, K_i, K_d, we've mentioned above, we end up with an optimal set of parameters which can meet our requirements.

Table 3.2.1.1 The optimal set of PID parameters

Parameter	K_p	K_i	K_d
Value	3	2.1	2.5



(a) Actual linear velocities of each wheel with the optimal set of parameters

(b) Actual linear velocities of each wheel with lower target value

Figure 3.2.1.1 Feedback values for real-time monitoring from encoders

Although this set of parameters can make the algorithm quickly converge to the target value, there is always strong fluctuations in the start-up phase, as shown in figure 3.2.1.1 (a). The only method we've found to avoid this kind of strong fluctuation is to decrease the target value we set, like the situation in figure 3.2.1.1 (b). However, we have to reduce the target value to the half of its original value, from 40cm/s to 20cm/s, in order to avoid the fluctuation. Considering that the velocity of motion is also an important factor in this project, we finally choose to bear this fluctuation and damp down this fluctuation by other methods.

b) Launching System

Figure 3.2.2.1(a) shows three generations of steel rods combination of different length, radii and number. At the beginning, we used an 8mm steel rod as a lever. Since there is only one steel rod, it is easy to deflect when installing the basket, resulting in the deviation of the launching direction. Two 4mm steel rods and two installation holes can ensure that the basket will not occur Axial rotation. Because the tension of the spring is very large, when the hook depresses the lever, the lever deformation will be very serious, which will affect the stability of the launch. Thus, we replace the two 4mm steel rods used at the beginning with 6mm steel rods.

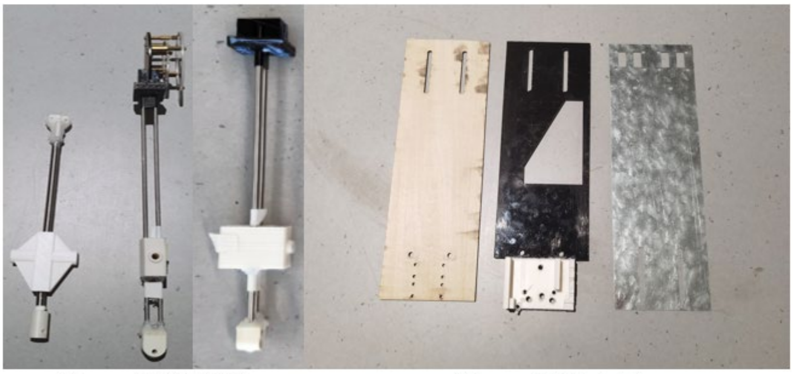


Figure 3.2.2.1 (a) Figure 3.2.2.1 (b)

Figure 3.2.2.1 (a) Three generations of steel rod combination;
(b) Three generations of launch basis

Figure 3.2.2.1 (b) shows the iterative process of bottom plate of different material for the launching system. At the beginning, the acrylic plate was used as the bottom plate of the launching system, but due to the fact that the spring force is so strong that the acrylic plate will be seriously deformed and even broken after repeated use. Thus, we replace the acrylic plate with a steel plate, which is also deformed after several times of experiments. At the end, we used two layers of steel plate, and the deformation of plate is greatly reduced.

The strength of the 3D-print lever support and spring mounting seat are insufficient leading to the result that they are easy to break. The use of acrylic structure saves the manufacturing time and greatly improves these structures' strength.

Due to the error in the position of the hole in the 3D print parts, the inner diameter of the hole will be smaller than the outer diameter, which make the steel rod cannot be installed into these 3D print structures. Then we increase the hole diameter of the printed structures and the steel rod can be installed smoothly. But due to the large hole radius, the steel rod will rotate in the hole, resulting in a deviation in the direction of the basket. We tested a variety of holes of different radius and found the one that just fits snugly with the steel rod, which greatly increases the stability of the entire structure and the accuracy of launching.

c) Reloading System

In experiment, we first reload racket balls and ping-pong balls. Then, reload tennis balls and ping-pong balls. The reloading of ping-pong ball and tennis ball perform quite well.

But we discover that we need to shoot racket balls at first after one reload, because the large friction force between the inner surface of the clip and the racket ball makes the racket ball cannot be lifted once the racket ball is compressed by the inner surface of the clip. In case of this compression, we let the racket ball drop down by making the servo motor reverse its direction of rotation.

IV. Discussion

The innovate part is the baffle board is detachable. Every cell can hold one ping-pong ball or racket ball. If you want to hold a tennis ball, you can take down the baffle board between two adjacent cells, so that you can get larger space to load tennis ball.

Comparing the two versions of launching system, the advantage of the Version II is that the rotary motion of the lever is converted into the translational motion of the servo motor, forming a set of high energy-efficiency structure. And the torque demand for the servo motor and the stepper motor are also greatly reduced. Therefore, we can use more cheaper element devices. We use steel rods, acrylic plates, and PLA to make the version II of launching system. Acrylic and steel are used for key stress-bearing parts, and PLA materials are used for some complex structures with little stress.

V. Cost Estimation

As for the cost estimation for the entire project, we first allocate all costs into four major aspects: consumable components, 3D-print Structures, electronic components and functional components. Then, we enumerate costs of all items we've purchased and calculate costs of these four aspects. Add them up we can get the total cost for this project. Figure 5.1 shows the detail of this process.

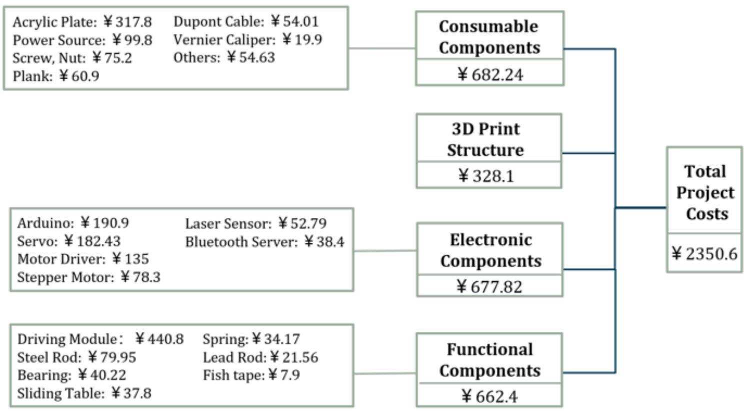


Figure 5.1 Detail of the calculating process for the total project cost

In addition, we calculate the total cost for the four systems of our project and the detail cost of each system by the same allocating method, as shown in figure 5.2. By comparison, we find that the driving system and the launching system cost the most. But the expenditure on functional components, mainly the Driving Module containing four DC geared motors, four omni wheels and four motor drivers, accounts for the most in driving system, while these four sub-costs are almost equal in launching system.

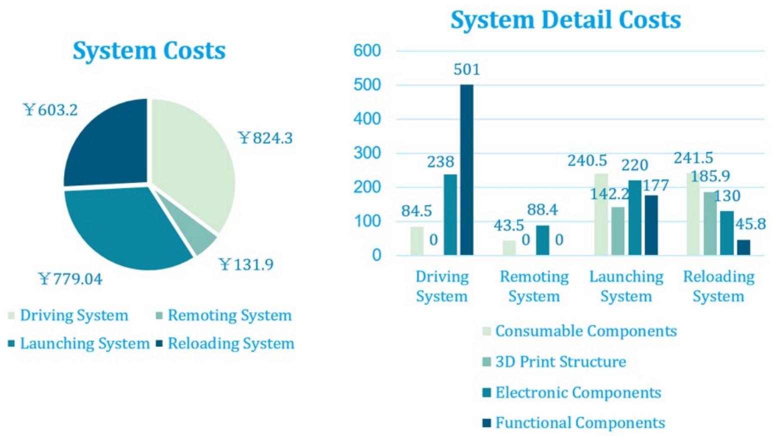


Figure 5.2 Detail costs of each system

VI. Conclusion

At the end of this project, we can draw a conclusion that our product performs quite well in every aspect. We are the bronze medalist in the Game Day and got 8.8 points in total. If more time allowed, I believe that we can continue to improve our project and make it better. For example, we can try to add some control algorithm to help us make it aim at the target basket, which can improve our launching accuracy in some extent…

Last but not least, all of our five team members have improved ourselves during in this project, not only the knowledge we learned and the skills or abilities we improved, but also the team spirit we persist: help each other, and overcome difficulties together.

VII. Reference

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Artificial Intelligence.

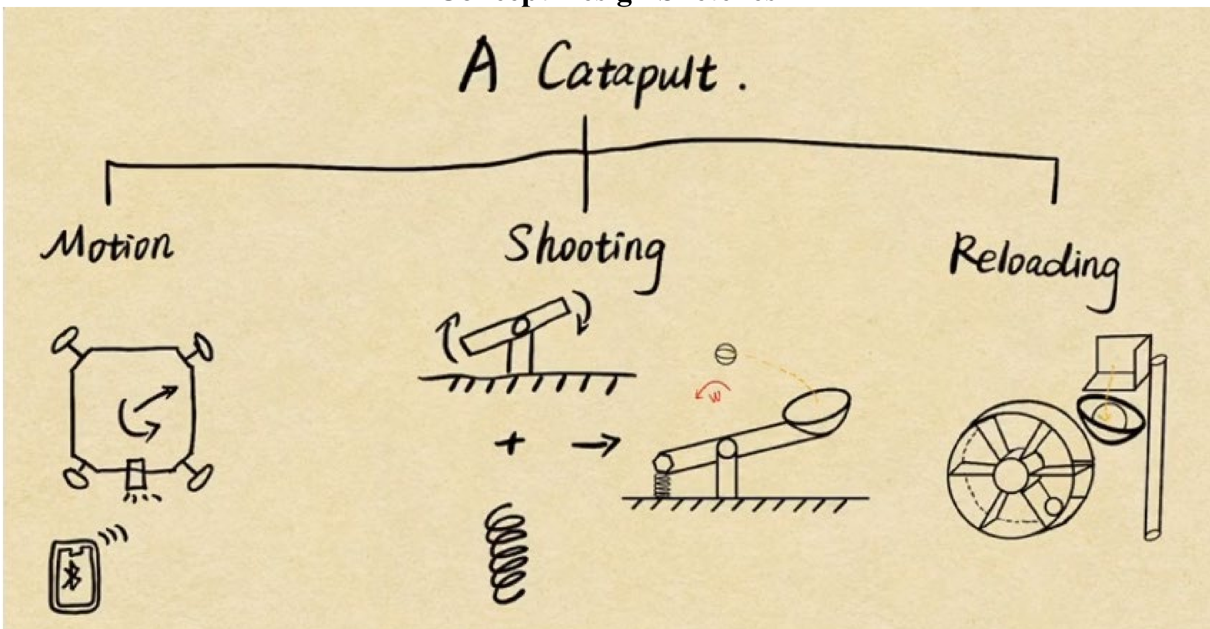
[3] Oliveira, H.P., Sousa, A., Moreira, A.P., & Costa, P.J. (2008). Precise modeling of a four wheeled omni-directional robot.

VIII. Acknowledgement

Sincere thanks to SHI-MING WU SCHOOL OF INTELLIGENT MANUFACTURING, Prof. Yingjie Zhang, all people who have helped this project, and all the team members of SharpShooter.

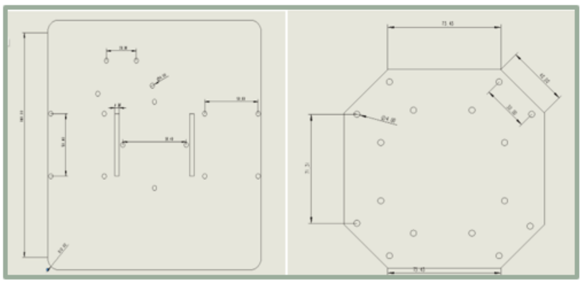
IX. Appendix I

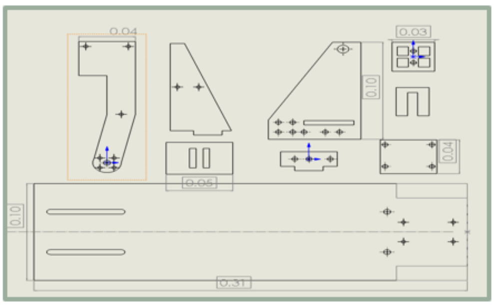
Concept Design Sketches

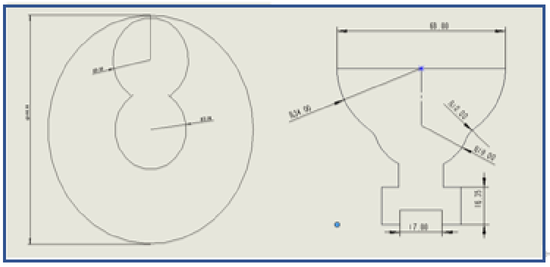


X. Appendix II

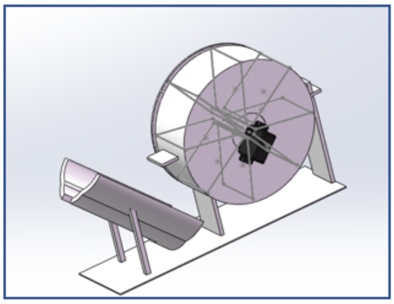
Engineering Drawings with SolidWorks


Drawings of Driving System

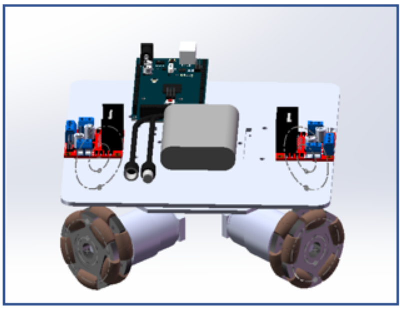

Drawings of launching system



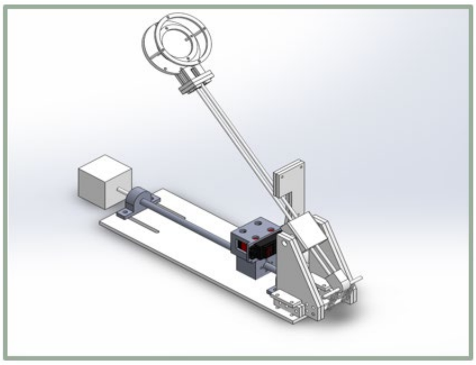
Drawings of Reloading system



Model of Reloading system



Model of driving system



Model of launching system

XI. Appendix III

Product Design Specifications

Product design specification

Product Identification

- ◻ Omni-motion, Remote-control and Self-reloading Catapult
- ◻ Function:
- • Omni-motion
- • Remote control
- • Balls storing
- • Balls shooting
- • Self-reloading
- • Steering
- • Adaptable to 3 kinds of balls
- ◻ Special features:
- • Collimation
- • Laser ranging

- ◻ Key performance targets:
- • Launch range: 2.5m±0.1m
- • Target range: 20x20x20cm
- • Flexible steering
- • Precise braking
- • Simple operation
- • High stability

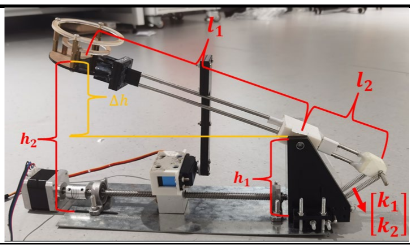
Key project deadlines

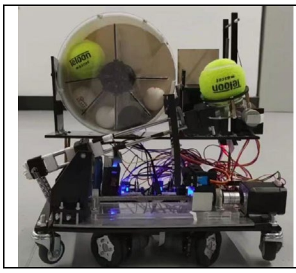
- • Project report: 29th May
- • Project: 10th June

XII. Appendix IV

Detail Parameters of the Final Product

Number	Inner Diameter	Outer Diameter
1	1mm	5mm
2	1mm	8mm
3	0.8mm	6mm
4	0.8mm	8mm

	l_1	l_2	h_1	h_2	Δh
	21cm	8cm	11.5cm	21.5cm	10cm

	Length	Width	Height
	35cm	20cm	36cm

XIII. Appendix V

Bluetooth Android Application Development


运动控制
点击模式
长按模式
左前
前进
右前
左
停止
右
左后
后退
右后
顺转
逆转
蓝牙连接
发送指令
运动控制
长按模式
点击模式
长按模式
左前
前进
右前
左
停止
右
左后
后退
右后
顺转
逆转
蓝牙连接
发送指令
运动控制