Mechanical Design Principles Report

Group 4

Car Name: Scallion Aaron

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2021/1/7

范雲鴻

周佑綸

陳子鈞

賴昭蓉

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I. Team Structure

Detailed division of labor:

Hua Yunhong: Circuitry, programming, purchasing some materials, laser cutting machine and 3D printer operation.

Zhou Youlun: Assemble the vehicle body, assist with wiring, some CAD drawings, and handle materials.

Chen Zijun: Operation of laser cutting machine and 3D printer, material handling, and vehicle assembly.

Lai Zhaorong: Mechanical design, CAD drawings, vehicle assembly, and material handling.

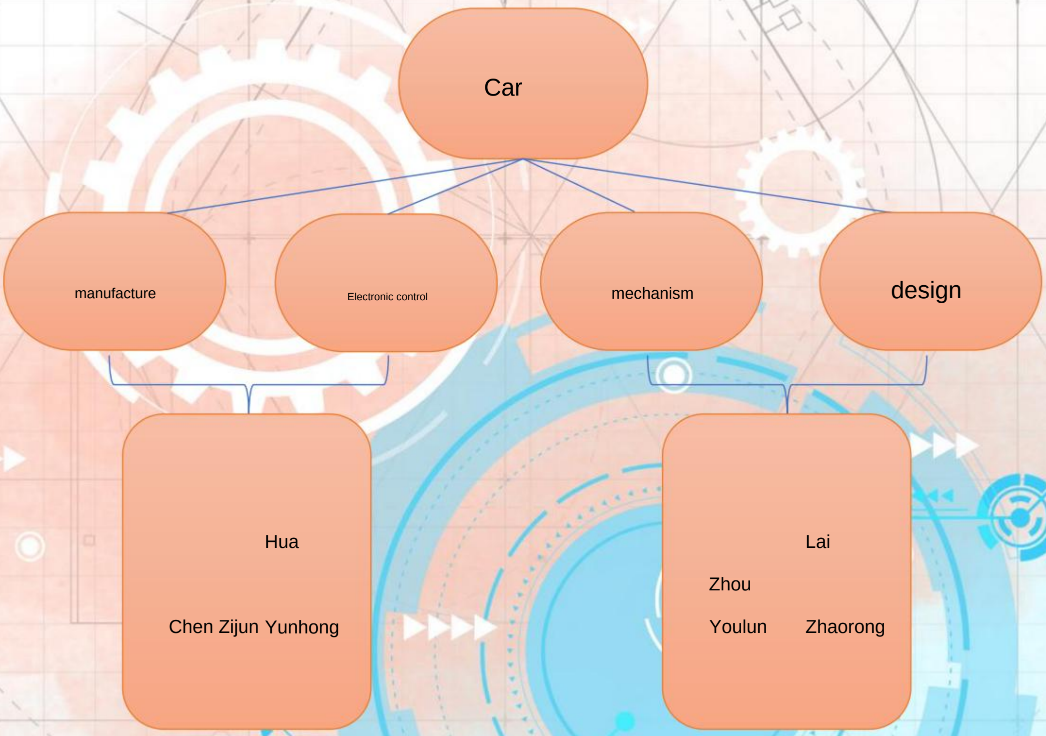


Figure 1 Work Assignment Diagram

II. Introduction to the Billiard Car

Our billiard car – Onion Aaron – has the following features:

The billiard car designed by our team is set in a land-based, horizontal movement environment and needs to be stable and precise.

Based on the principle that the ball can launch approximately 50g of marbles, we designed the billiard car with the following features:

1. Stable movement

Our team uses the MG996R servo motor as its power source. It has a strength exceeding 11 kg/cm².

The powerful torque, combined with the team's custom-made tire covers, allows their billiard cart to glide smoothly on slippery surfaces.

The surface also provides good grip. The MG996R is also suitable for use in small robots of this type.

In short-distance travel, precise control of spin speed facilitates fine-tuning of the striking position. Meanwhile, the servo motor...

When stationary, it has a self-locking property, which helps us stabilize the vehicle when hitting the ball.

2. Powerful firing mechanism

The team's designed billiard cart aims to launch marbles with a diameter of 35mm and a weight of 50g. (Marble transport...)

During the journey, it is also necessary to overcome the unevenness of the terrain and friction. Therefore, we designed a powerful...

The striking mechanism uses an MG996R motor to drive a cam mechanism to store power, and after calculation and evaluation...

The 08100 spring is selected for energy storage, and the cam stroke ensures that the ball can move on the field.

Long-distance, precise shot movement.

3. User-friendly interface

Our team chose the PS2 remote control as the control interface. This remote control has many redundant buttons, making...

We were able to incorporate the concept of human factors engineering, receiving feedback from drivers on their remote control experiences after driving, and continuously improve our technology.

The intuitiveness of the user interface allows operators to control the device in the most user-friendly way, achieving greater agility.

Remote control response time. Furthermore, it features two adjustable wheel speeds to adapt to various racing conditions.

Depending on the situation, move precisely to the optimal hitting angle and position.

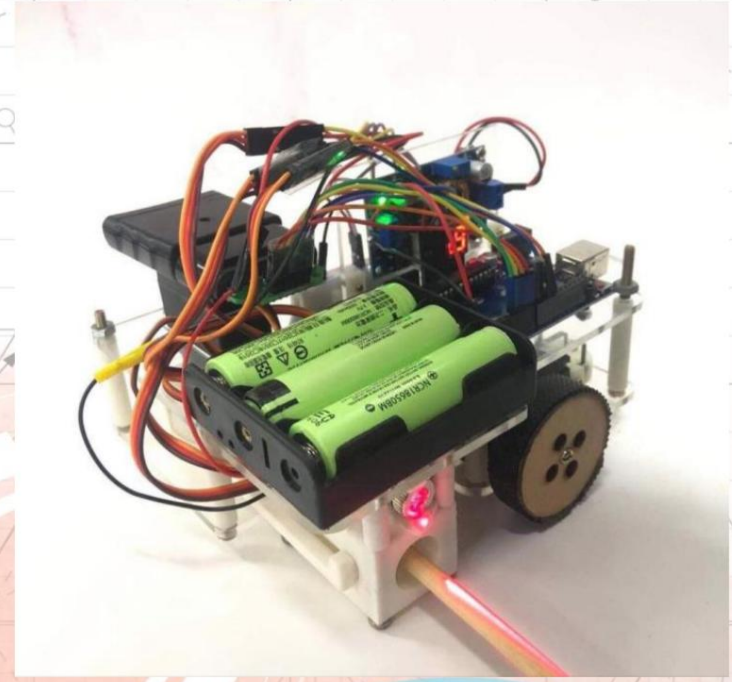


Figure 2 shows the actual billiard car (final version).

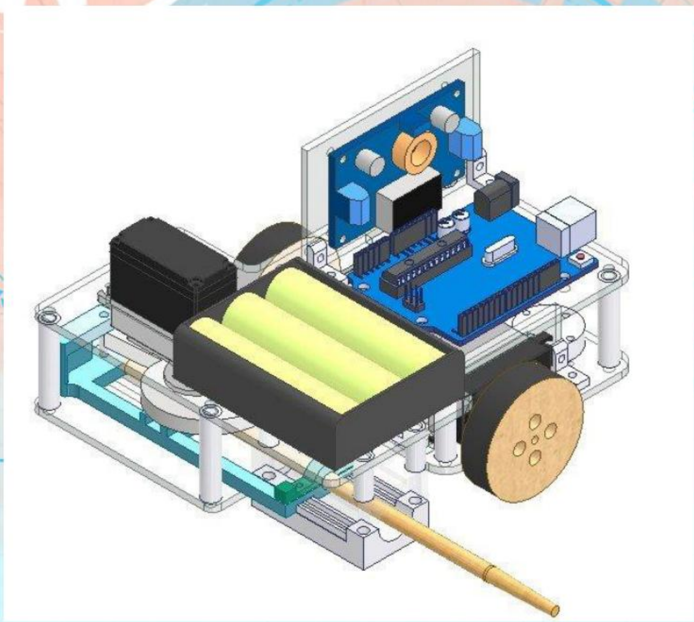


Figure 3. Simulation diagram of the ball-bumper car inventory (final version)

III. Design Methods

1. Teamwork skills

(1) Listening instead of speaking

When group members are expressing their opinions, the most important thing to do is not to speak, but to listen carefully to the group members.

Their opinions can help us understand the other party's situation and shorten the time required to resolve the problem.

(2) Practice empathy

To understand and offer constructive feedback to those who hold differing viewpoints, and to consider everyone's perspective.

These are all things that must be considered.

(3) Accepting feedback

When team members offer feedback and opinions on completed tasks, it is equivalent to providing...

Seek perspectives from the same viewpoint, try to accept feedback, and think about solutions.

(4) Try to express yourself clearly

To avoid misunderstandings or reduced efficiency, opinions should be expressed specifically and...

Clearly describe the problem or opinion.

2. Team Agreement

(1) Meet at least once a week.

(2) You must not be late for meetings.

(3) Prepare for each meeting in order to facilitate the meeting.

(4) Check the group for important messages at least once a day.

(5) Solve problems through communication.

(6) If you find it difficult to complete the work, ask your teammates for help or seek solutions immediately.

(7) The workload should be distributed as evenly as possible, and there should be no situation where it is too heavy or too light.

(8) Materials must not be purchased at will; all material purchases must be approved by the entire group.

(9) Invoices must be provided for the purchase of materials for financial management and reimbursement.

(10) Any changes or additions to the convention must be agreed upon by the entire group.

3. Design Process

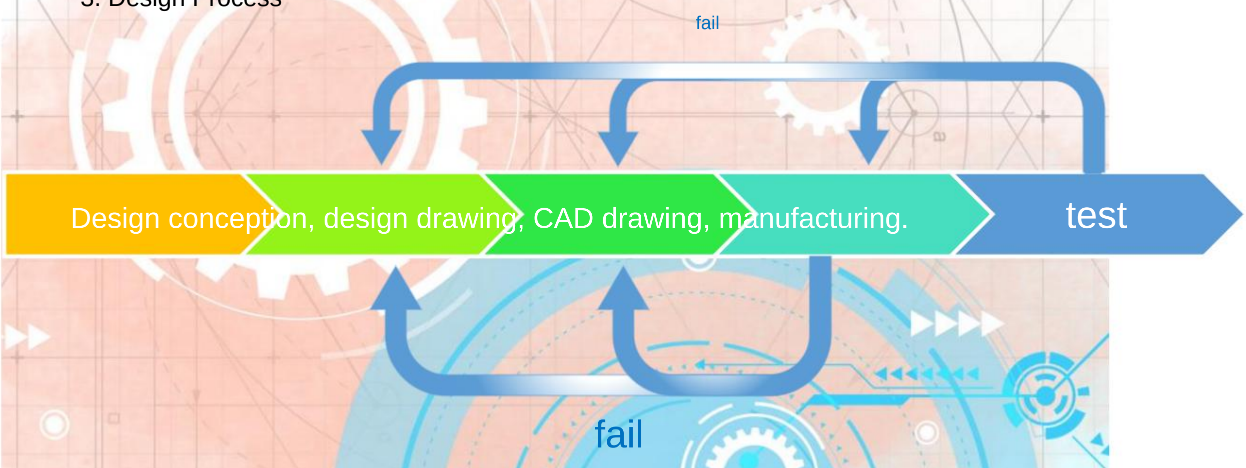


Figure 4 Design Flowchart

4. Formulas and equations used

1. Solid length of the spring ( ): Refer to Figure 5. Here, this group selects Square and

The spring on the ground, given the following conditions: ÿ ÿ The required value is d.

Term	Type of Spring Ends: Plain	Plain and Ground	Squared or Closed	Squared and Ground
End coils, N_e	0	1	2	2
Total coils, N_t	N_a	$N_a + 1$	$N_a + 2$	$N_a + 2$
Free length, L_0	$pN_a + d$	$p(N_a + 1)$	$pN_a + 3d$	$pN_a + 2d$
Solid length, L_s	$d(N_t + 1)$	dN_t	$d(N_t + 1)$	dN_t
Pitch, p	$(L_0 - d)/N_a$	$L_0/(N_a + 1)$	$(L_0 - 3d)/N_a$	$(L_0 - 2d)/N_a$

Figure 5

Note: The calculated value represents the spring's maximum compression (minimum value), but in reality, it will only compress to a certain extent.

ÿ < This is to prevent the spring from undergoing permanent deformation.

2.Spring constant (k) ÿk ÿ 4 / 8 3

3. Spring striking force ÿ = (ÿ)

Note: ÿ This is the maximum length of the spring at the moment of firing, which will be less than the Free length (0).

ÿ < 0

4. Equation of the cam curve: r() = (15 + 25 (a 360deg)) × 1

Note: The maximum radius is the maximum radius minus the minimum radius, d = ÿ = 40 ÿ

15 = 25, see Figure 6.

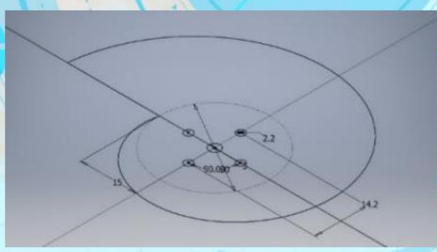


Figure 6. CAD of Cam

5. Bending moment (M) borne by the sliding member and caused by the M3 screw follower:

M = (ÿ) × (where (ÿ) is the restoring force of the spring under compression, under compression)

The effect of ÿ; d is the distance from the screw head to the contact point between the screw and the cam.

Note: This formula makes some idealized assumptions: it ignores the effect of friction, and the cam and...

The screw is a point contact screw.

5. Functions of each component and mechanism

(1) Clamping device:

A C-clamp mechanism is used to lock the upper and lower clamps together with two sets of screws and nuts (Figure 7). The lower clamp is round.

The upper half of the clamp is a rounded arc with a small section flattened (Figure 8), making the middle clamping space smaller and the clamping force more efficient.

The bamboo chopsticks are subjected to greater strain and have a stronger clamping force (Figure 9).

In addition, the position of the locking screw is designed as a component to fix the sliding direction of the slide.

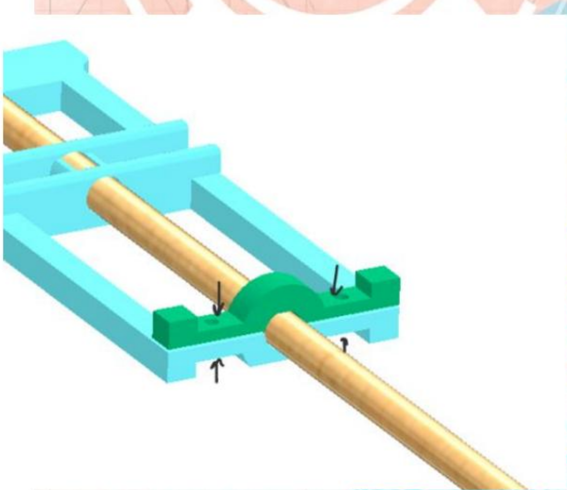
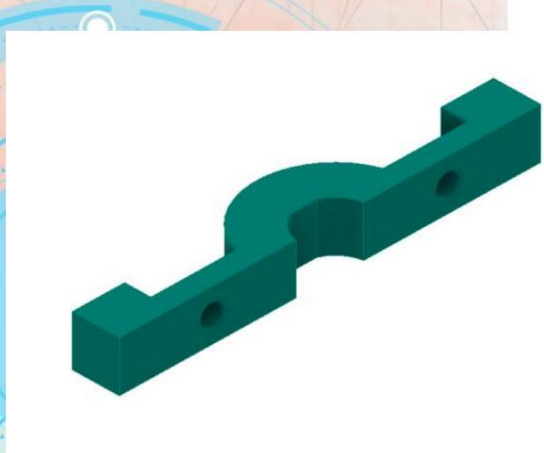


Figure 7 Schematic diagram of clamping lock fixing



The upper half of Figure 8 is a slightly flattened arc.

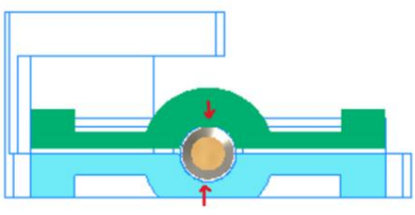


Figure 9 Force diagram of bamboo chopsticks

(2) Firing mechanism:

The front half of the firing mechanism is a spring box containing a spring, while the firing mechanism, equipped with a C-clamp, is...

The moving part slides on the tracks on both sides of the spring box. When it slides, the spring is compressed and then springs back up.

It will push the C-shaped clamp forward, causing the chopsticks to spring forward.

The spring box is designed with two separate halves for easy assembly, and also...

This can avoid having too much support material in the middle pores during 3D printing.

The rear half of the firing mechanism contains a cam drive device. An MG996 motor drives a discontinuous cam.

The cam rotates, and its profile is an involute (the radius increases linearly with the rotation angle). When the cam rotates...

When this happens, it will push the screw at the tail end of the driven component (Figure 10), at which point the spring in the spring box will...

When compressed, the cam radius will have a discontinuity after one revolution, causing the spring to release its elastic force.

Potential energy ejects the firing mechanism. (Figure 11)

The reason for using screws as driven components is that the material strength of 3D printed parts is not high.

The foot was prone to cracking, so a screw was used instead. The screw was then wrapped with 3M tape to prevent it from splitting.

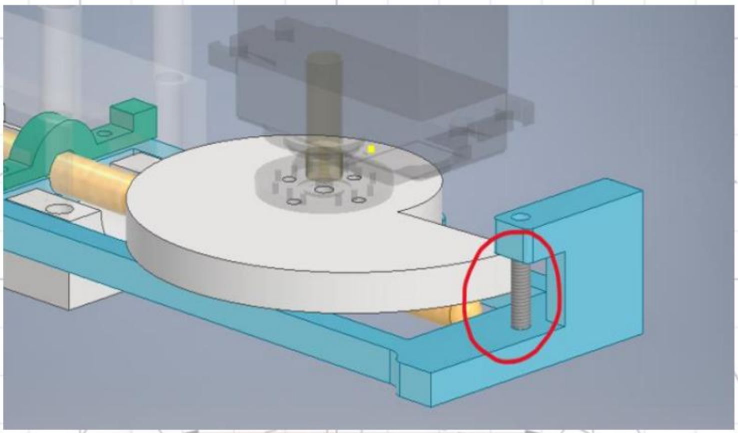


Figure 10 Screw as a driven component

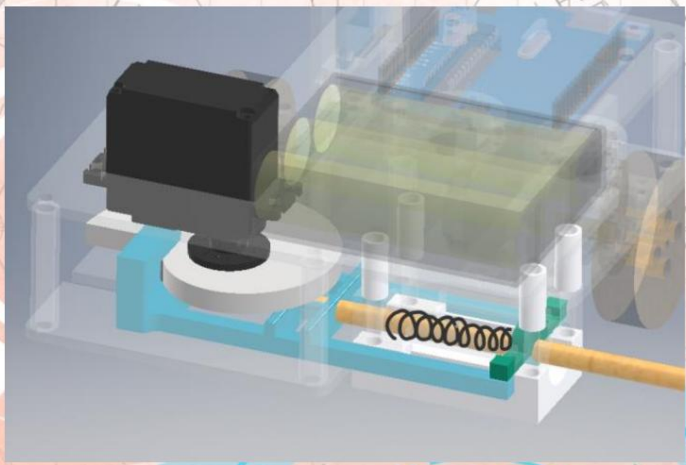


Figure 11 Firing mechanism (the upper half of the spring box is transparent)

The absence of threads increases cam resistance.

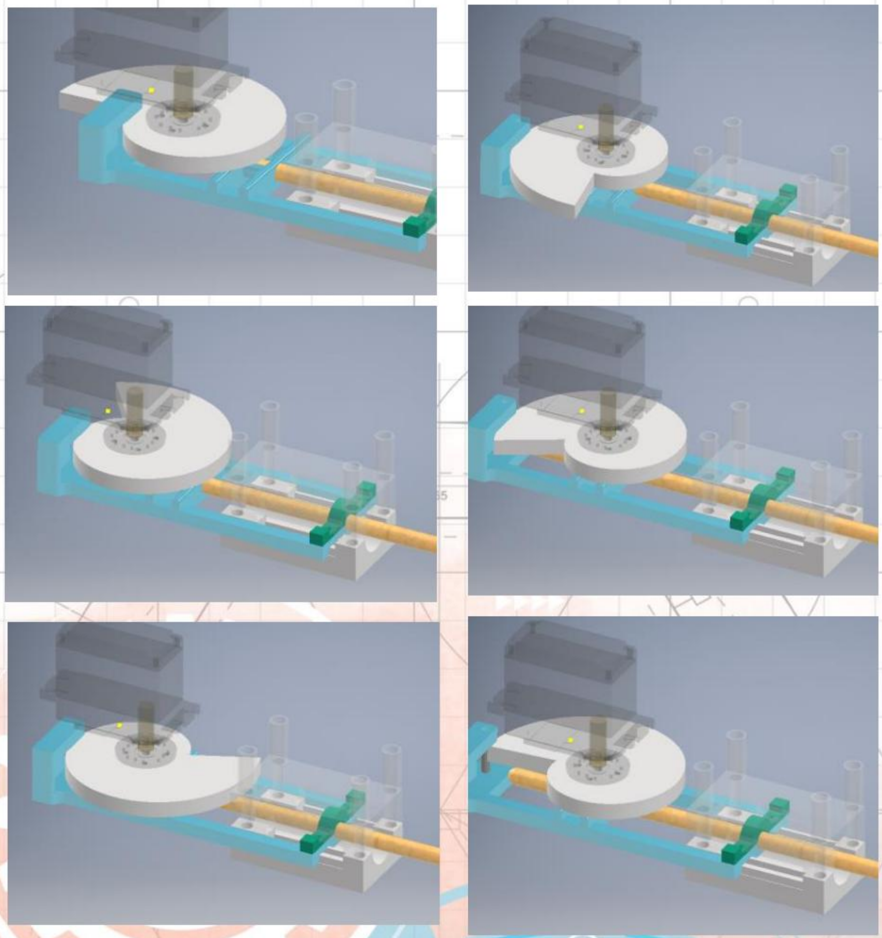


Figure 12 Schematic diagram of the cam-driven firing mechanism (spring omitted)

During the ejection process of the firing mechanism, it was discovered that the spring box slide rail had too many contact surfaces.

It often gets stuck due to excessive friction, causing the rear firing mechanism to bend downwards (see figure).

(13) Therefore, the upper and lower plates of the car body are designed to clamp the entire firing follower mechanism (Figure 14), so that...

It can only move forward and backward in a straight line. The sliding rail also has small grooves to prevent 3D movement.

The printing is too rough, resulting in excessive friction.

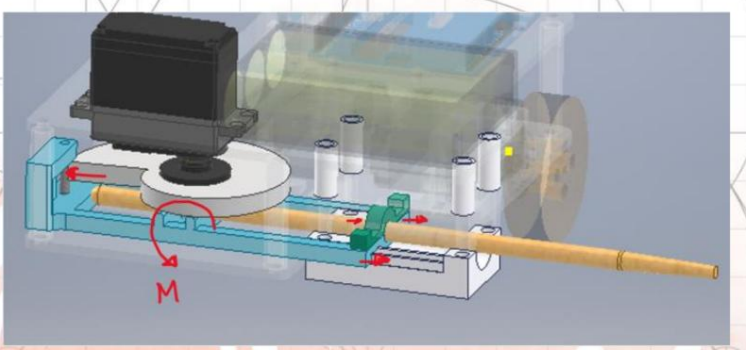


Figure 13. Schematic diagram of the firing mechanism when it is not supported and is bending.

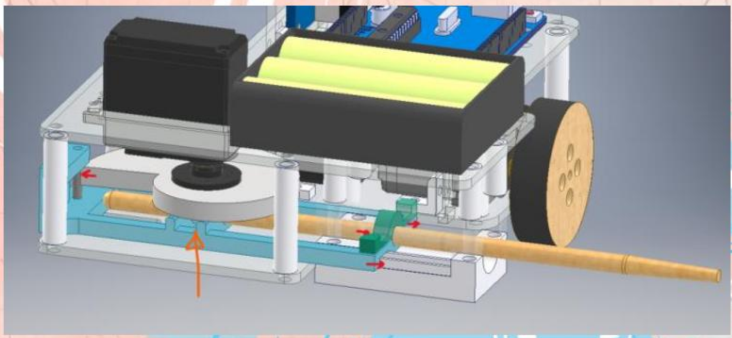


Figure 14 The firing device is supported by the upper and lower plates.

6. Circuit Design

This robot's electrical system design is divided into a large electrical system and a small electrical system. The large electrical system consists of three 18650 chips connected in series.

The voltage is stepped down to 7.1V using DC-DC rectification; while the smaller unit utilizes the 5V and 3.3V outputs from the Arduino.

In the middle, the power supply provided by the large power supply is for the MG996R and Arduino. The reason for choosing 7.1V is that this power supply...

The voltage is the intersection of the operating voltages of the two components. The receiver power supply for the PS2 joystick is connected to...

The Arduino receives a small 3.3V power supply and is grounded to the Arduino. The PS2 joystick has four other pins.

The 7, 6, 5, and 4 pins of the Arduino are connected for communication. The MG996R motor is connected to...

Pins 8, 10, and 11 of the Arduino are used to transmit Servo signals.

IV. Engineering Drawings

1. Concept sketch

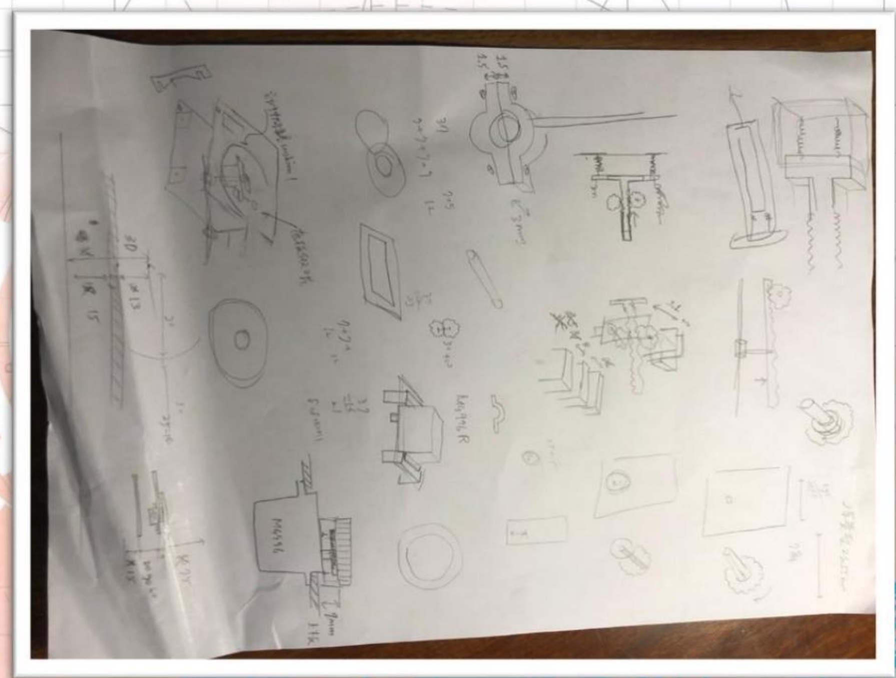


Figure 15. Draft diagram of the first generation firing mechanism

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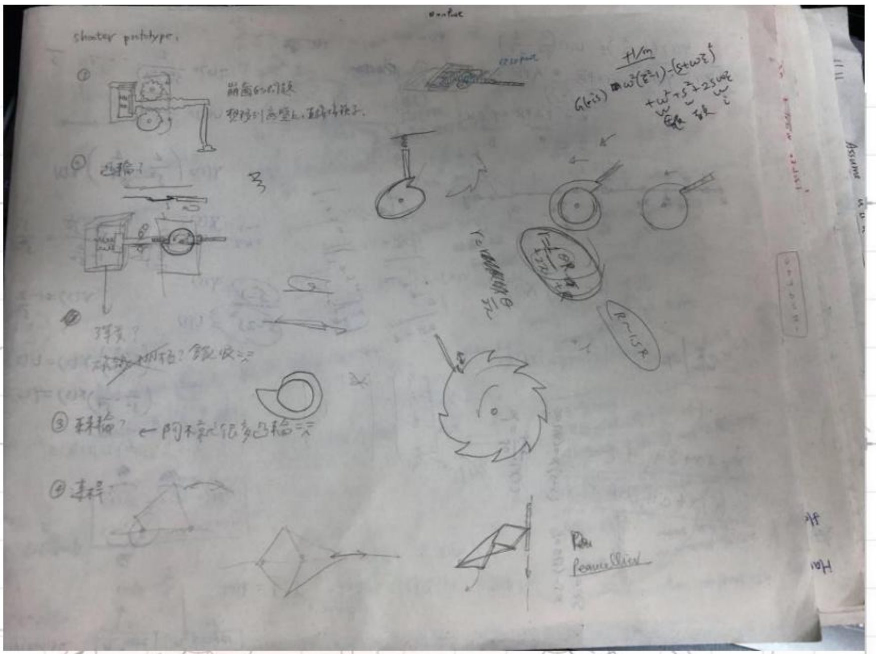


Figure 16. Initial draft diagram

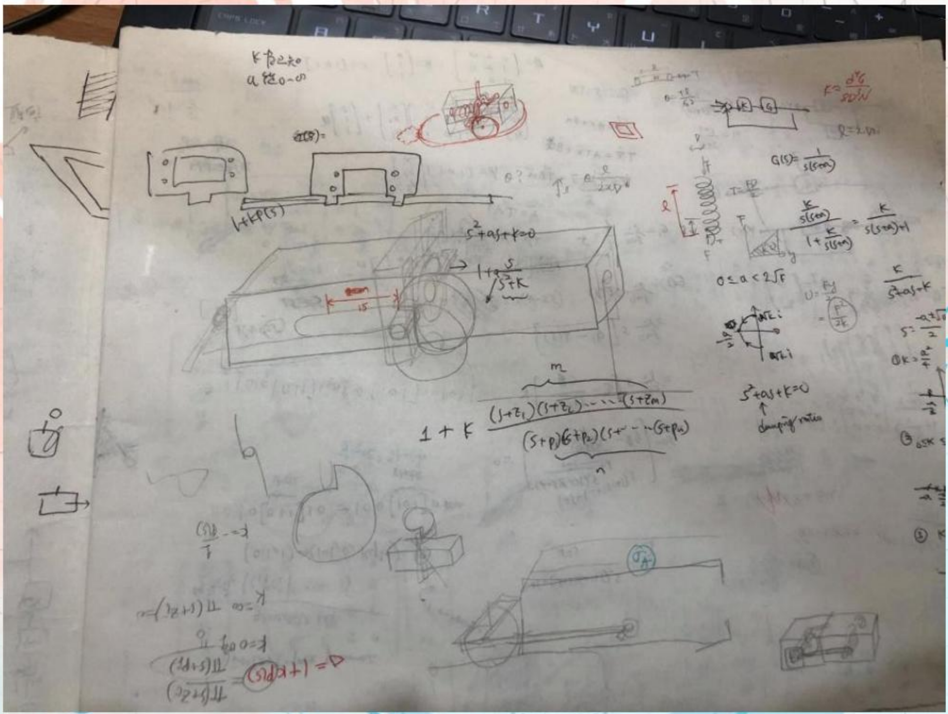


Figure 17. Draft drawing of a cam mechanism (I)

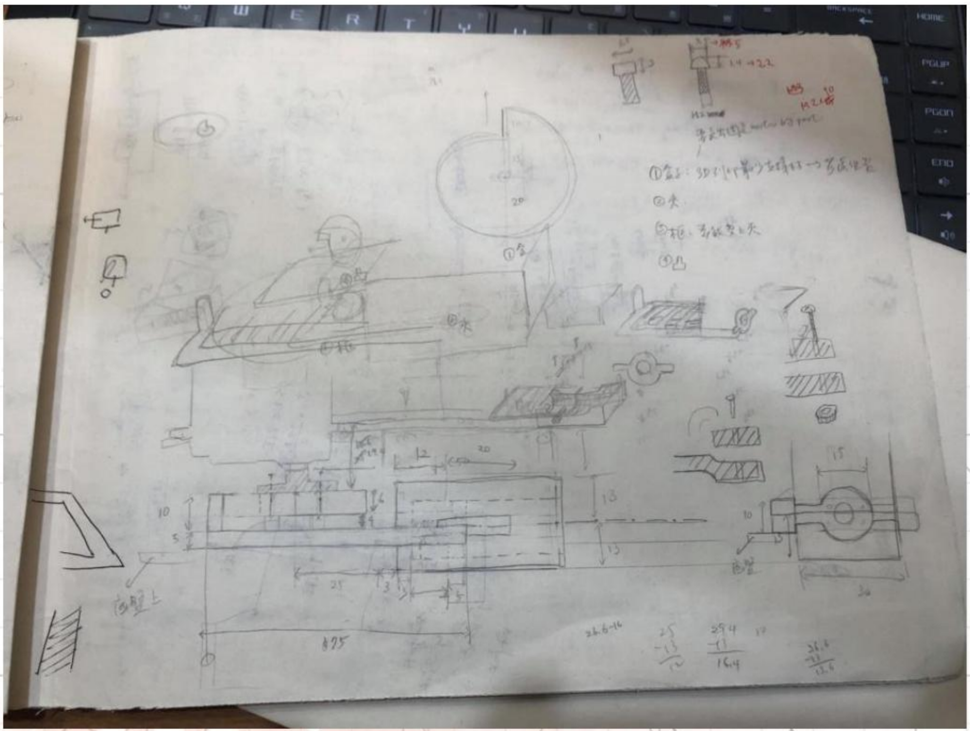


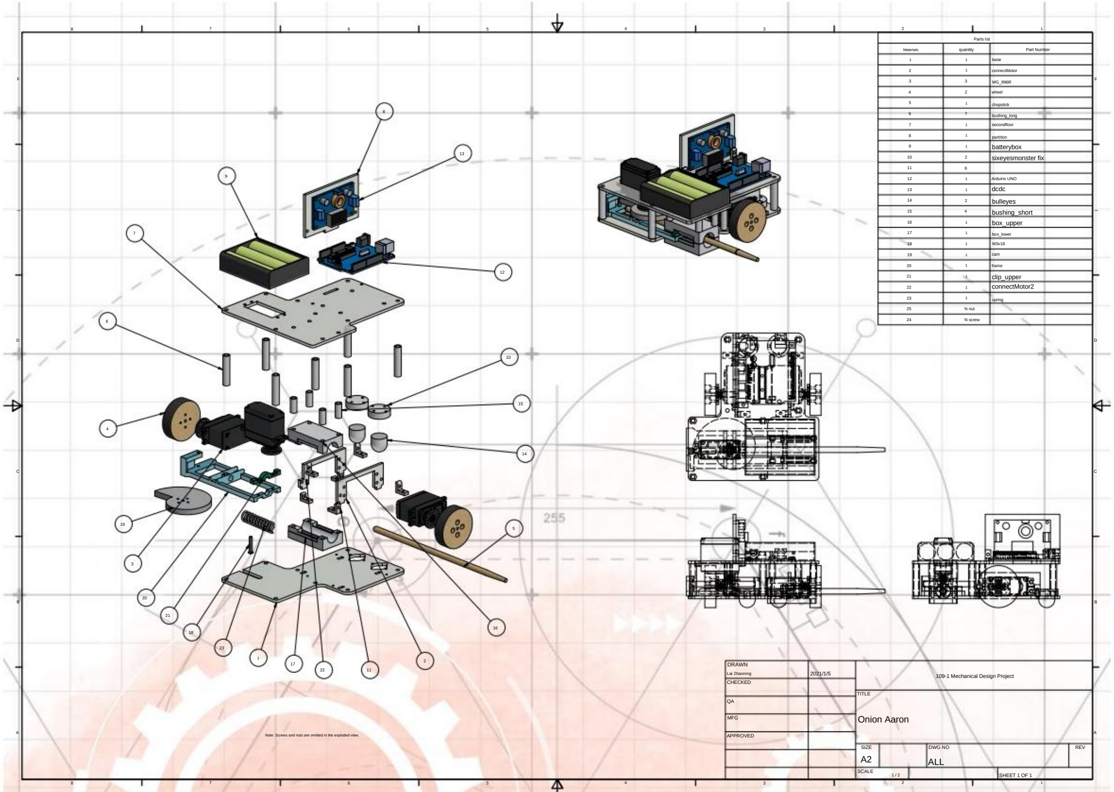
Figure 18. Draft drawing of the cam mechanism (II)

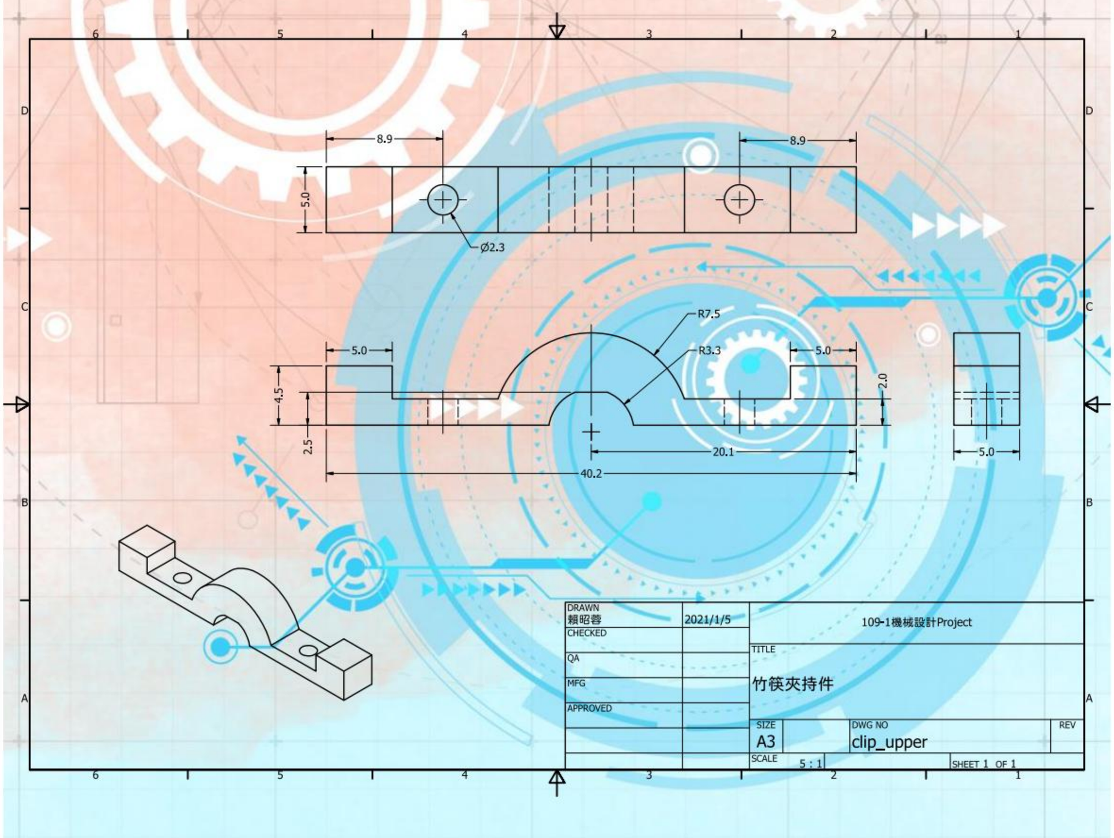
2. Bill of Materials (BOM)

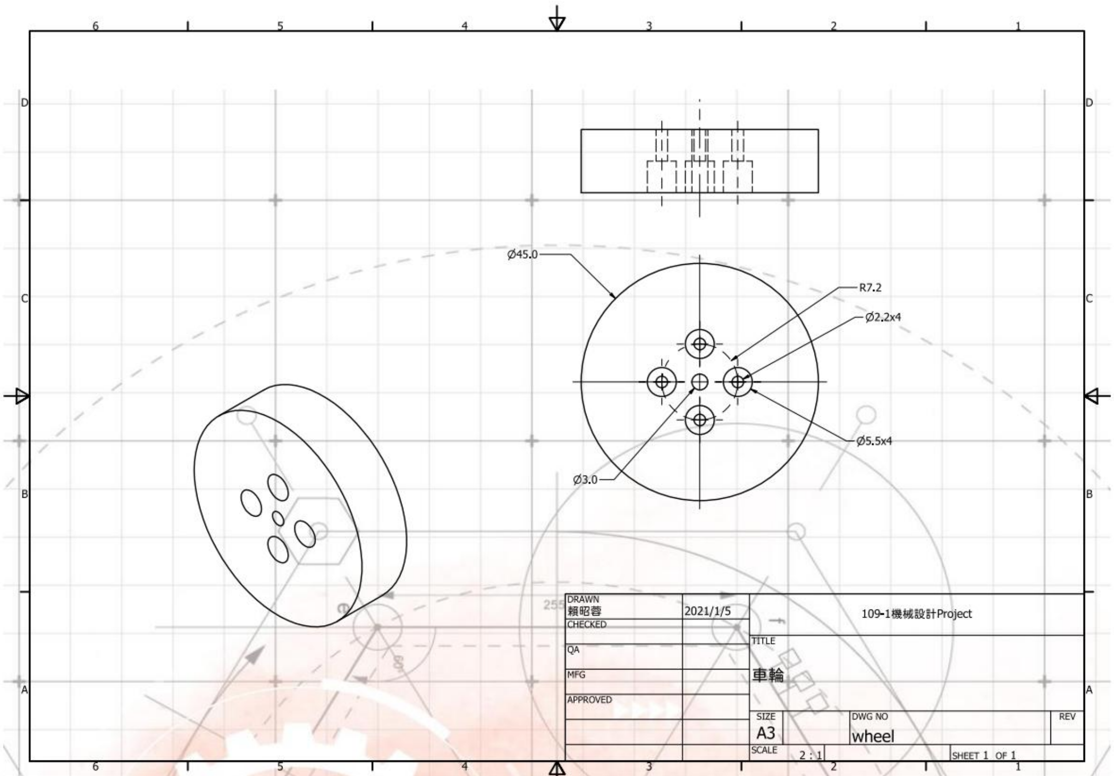
Items	quantity
vehicle body	
3mm acrylic shelf	2
Cam	1
Long bushing	7
short bushing	4
Activation follower	1

Vertical fixed version	6
3D printing wheel	4
swivel wheels	2
Spring top box	1
Spring lower box	1
Vientiane Bull's Eye	2
MG996R	3
3mm acrylic sheet	1
control	
PS2 remote control module	1
DC/DC converter module	1
18650 battery	3
breadboard	1
Arduino Uno	1
DuPont wire	N
spring	1
screw	N

3. Component drawings and non-standard part drawings



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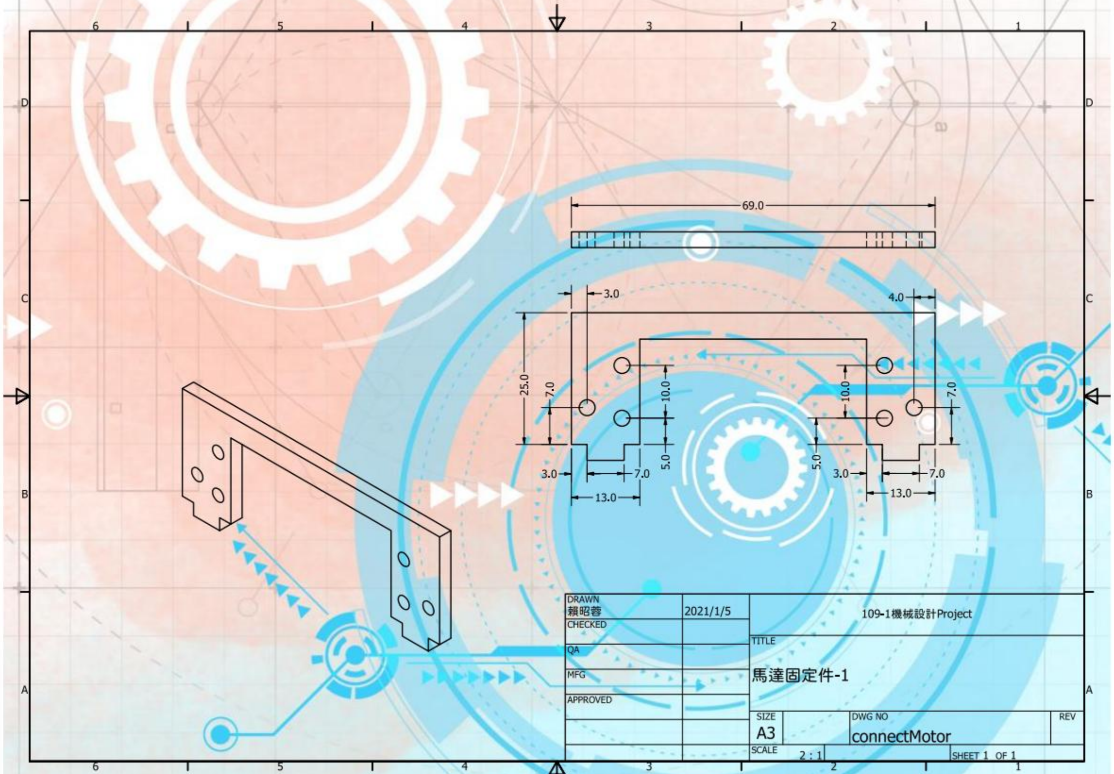
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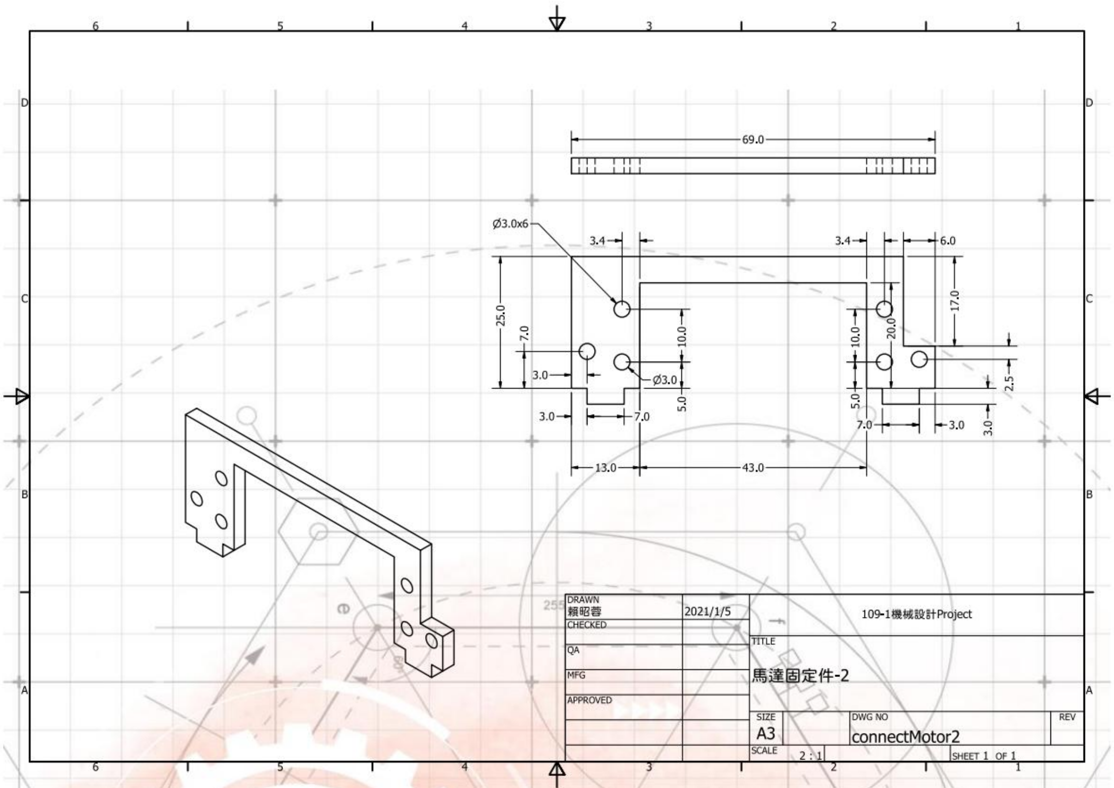
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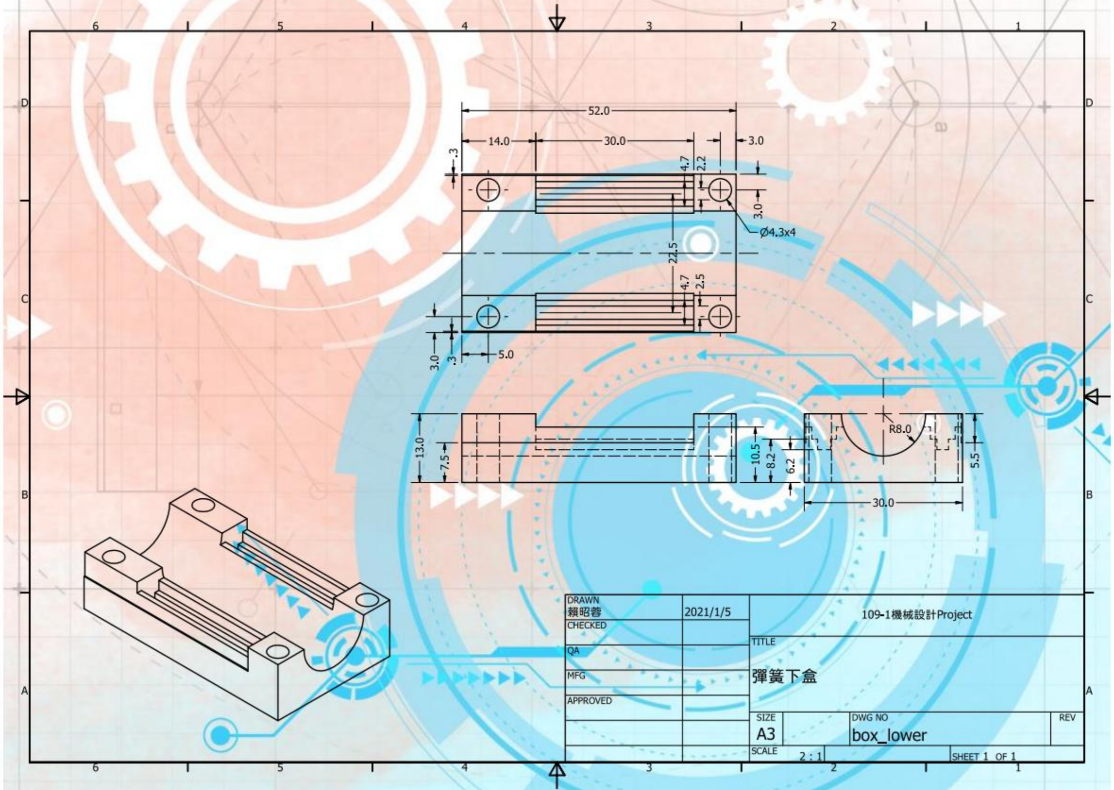
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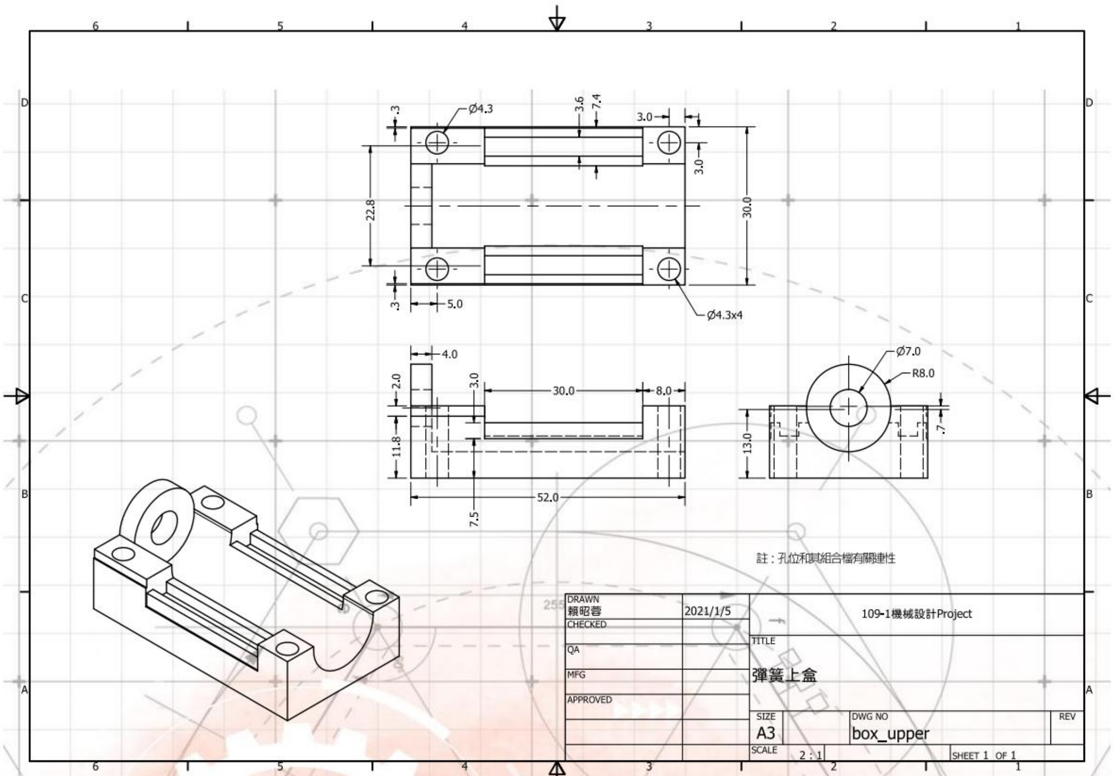
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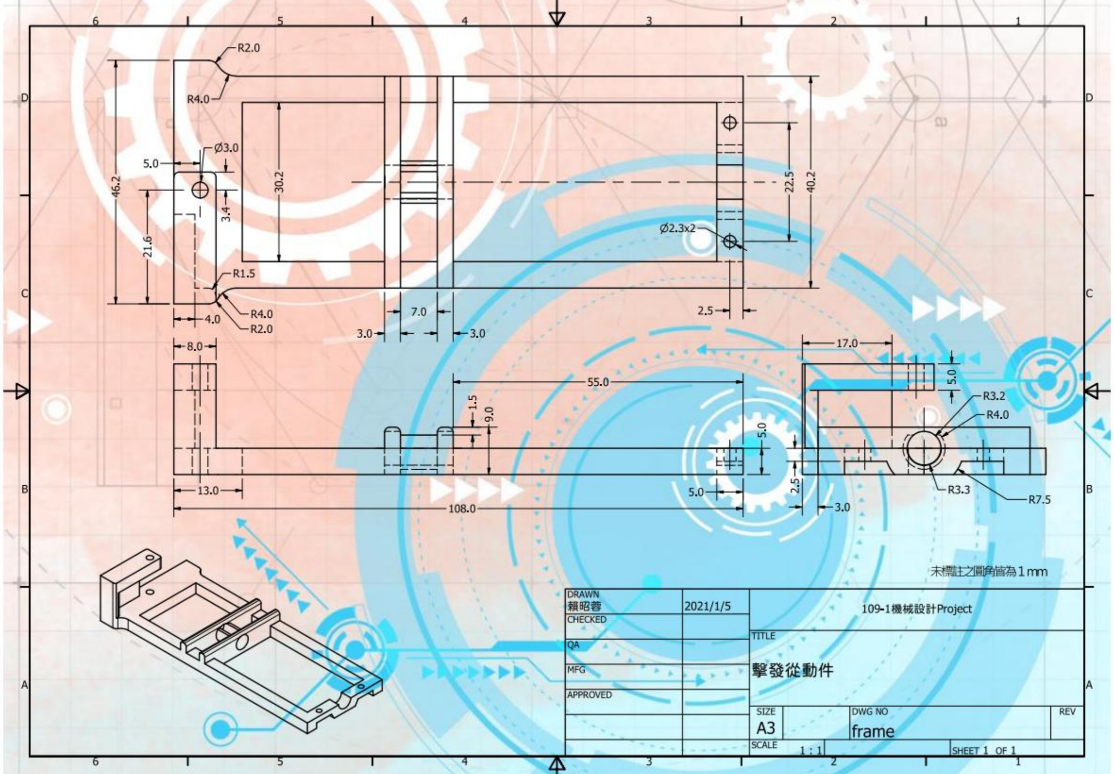
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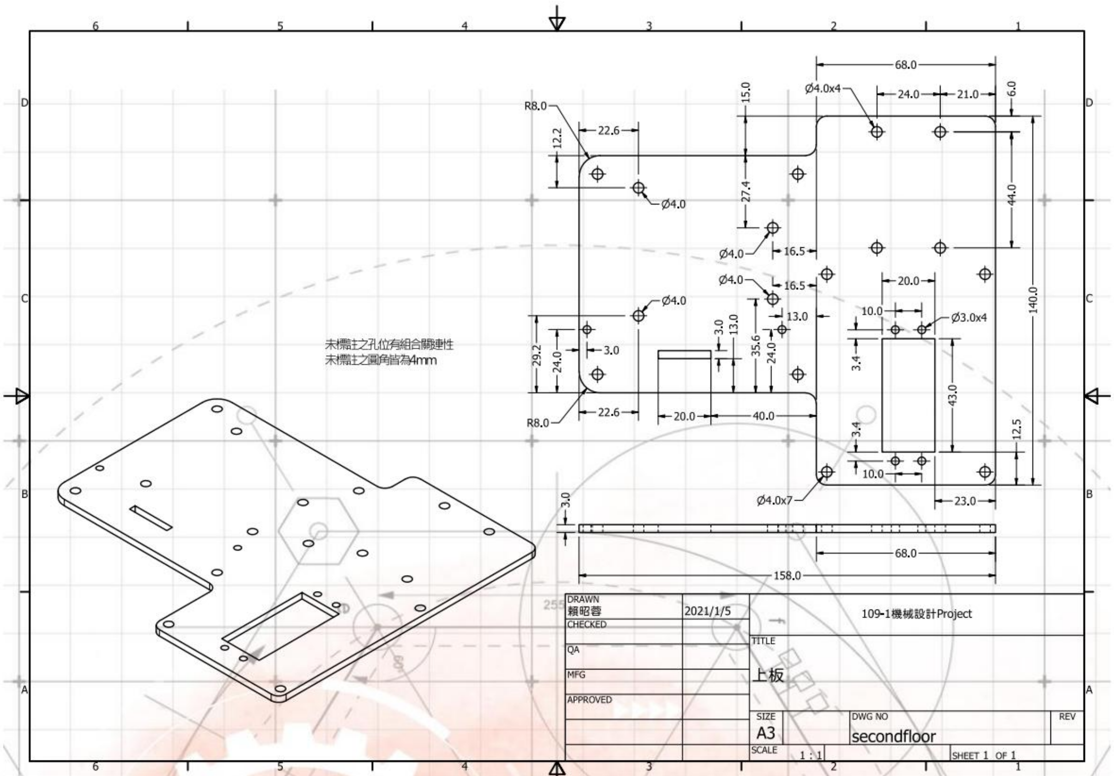
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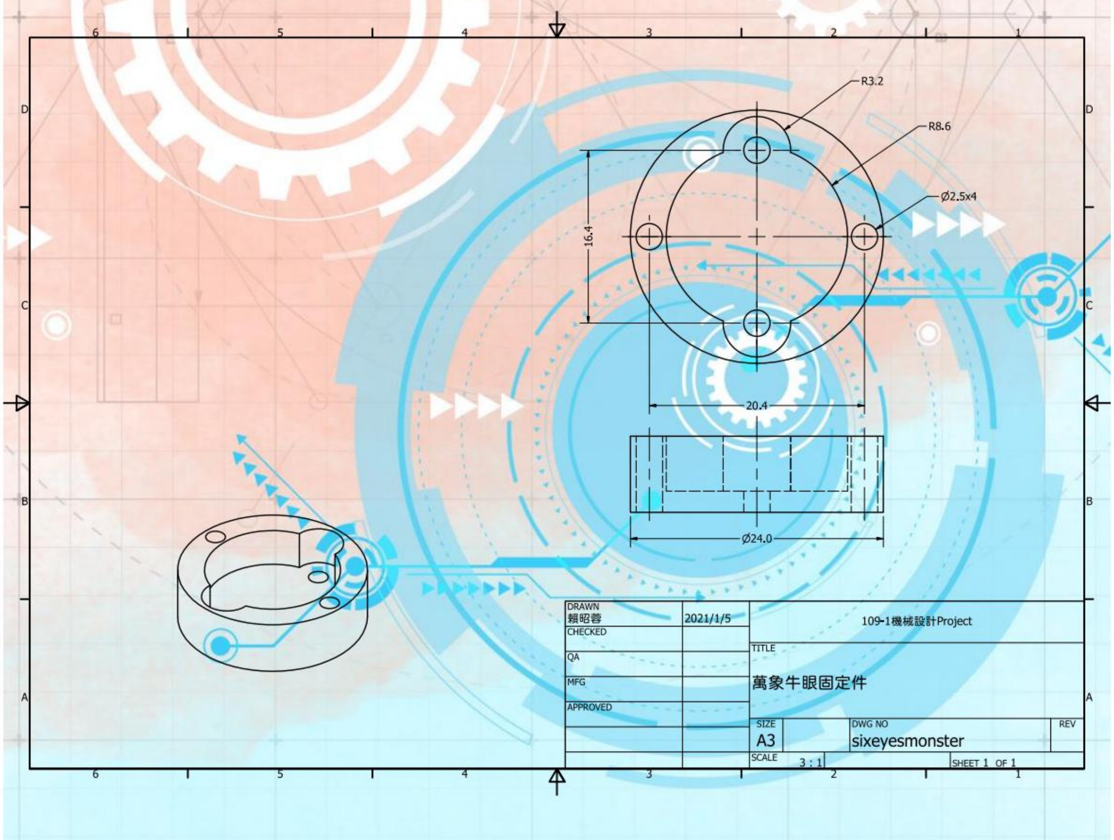
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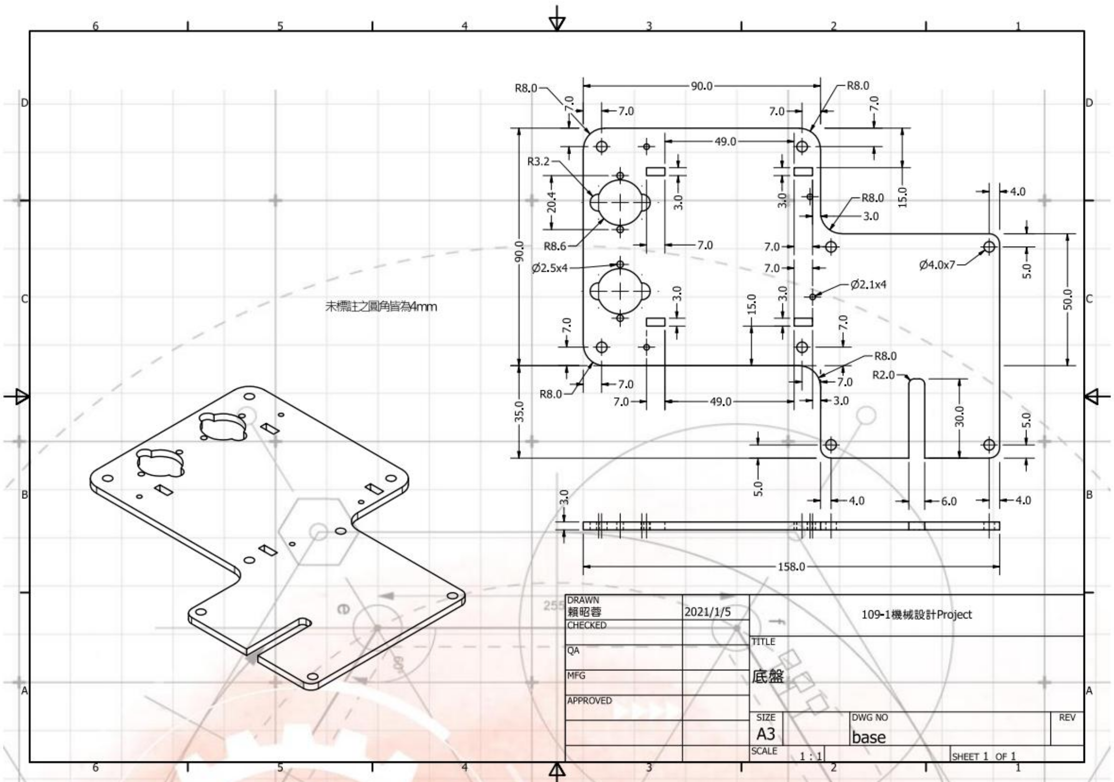
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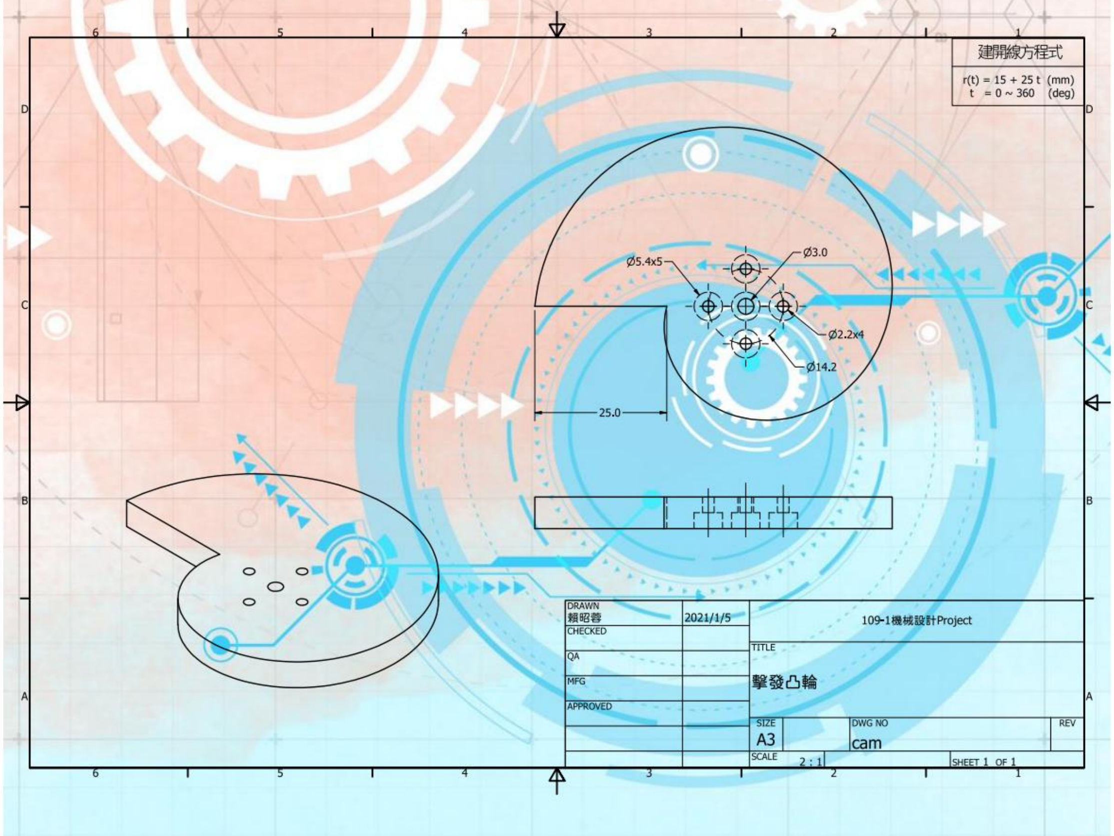
漸開線方程式
r(t) = 15 + 25 t (mm)
t = 0 ~ 360 (deg)
Ø5.4x5
Ø3.0
Ø2.2x4
Ø14.2
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DRAWN
賴昭蓉
2021/1/5
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MFG
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APPROVED
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cam
REV
SCALE
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SHEET 1 OF 1

V. Results and Discussion

1. Problems encountered and solutions during the design process

The design issues are mainly divided into three parts. The first part concerns the mechanical aspects.

Problems 1 through 6 are discussed; Part 2 concerns manufacturing issues; and Problems 7 through 6 are discussed.

9. Discussion: Part Three addresses the problems encountered during actual testing, and is discussed in Problems 10 and 11.

Part One: Institutions

Problem 1. The first firing mechanism in this group is a rack and pinion mechanism. During the actual test, it was found that the rack...

It may not engage with the gear every time it resets.

Solution: Calculate the number of teeth on the gear and rack so that they repeat exactly at the same point each time.

Alternatively, one could use a different institution.

Two solutions are provided above. Our group believes that solution two is easier to implement and therefore chose the more intuitive one.

Mechanism: Cam.

Note: The cams selected in this group are discontinuous cams, and therefore tend to be more like ratchet cams.

Problem 2. This group uses four-wheel drive, and the four servo motors in the chassis cause the firing mechanism to...

It cannot be installed in the chassis.

Solution: Move the firing mechanism to the rear of the vehicle body, with the firing direction to the right. And to eliminate the firing...

The bending at the connection between the mechanism and the upper plate (see Problem 4) extends the chassis to the meeting point.

The bending part is shown in the image below.

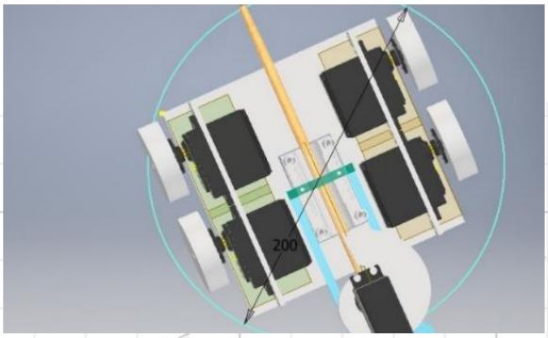


Figure 19. Vehicle body with the firing mechanism positioned in the very center.

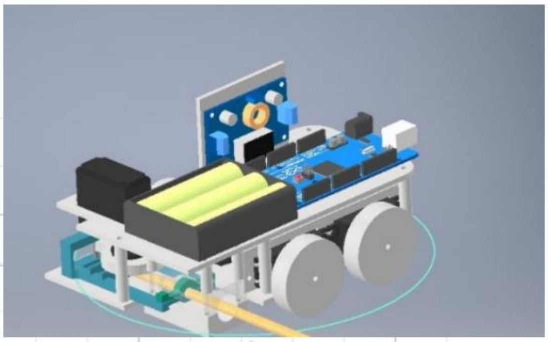


Figure 20. Improved vehicle body

Problem 3. After eliminating some problems in Problem 2, it was found that the entire firing mechanism and its components...

There is still bending at the connection point of the upper plate.

Solution: Extend the chassis made of MDF to the bending section to help with impact.

The mechanism resists the bending moment that causes bending, but the improvement effect is not good, which is presumably due to dense bending.

The board is not strong enough.

Alternative Solution: Replace the body material with acrylic, and add reinforcement between the upper panel and the chassis.

The 3D-printed car pillars significantly eliminate the bending effect! (See Figure 20)

two)

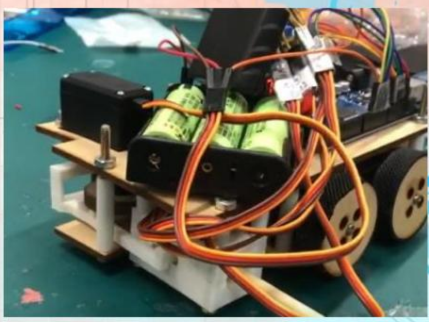


Figure 21. Vehicle body made of DPP (Dense Panel)

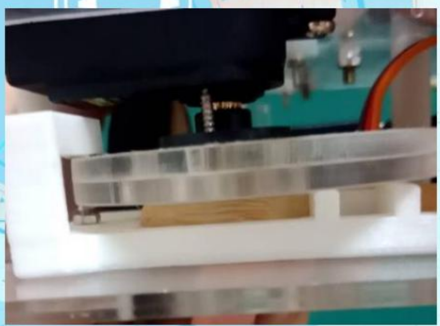


Figure 22. Acrylic car body

Problem 4. The spring initially selected was too small, resulting in a maximum travel distance of only about 10mm.

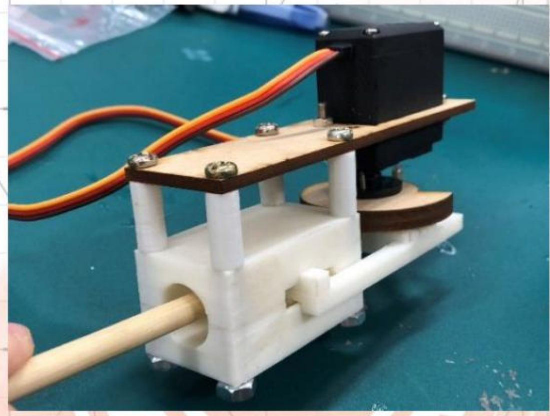
However, considering the aforementioned bending issue, the progress is reduced to approximately 3mm, which is very detrimental to the vehicle.

Aim and strike the ball.

Solution: Enlarge the cam (ratchet) to increase the progress from 10mm to 25mm, and

Purchase new springs (due to the increased spring length, i.e., a larger spring diameter, the length of the sliding component will also increase).

The length also needs to be increased. (See Figure 24)



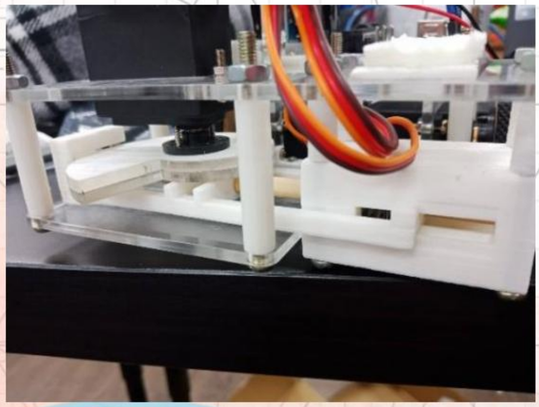


Figure 23. Firing device with a shorter firing process

Figure 24. Improved firing version

Derivative Problem: Due to the enlargement and lengthening of the cam and sliding components, coupled with the size of the vehicle body...

Due to limitations, the four servo motors originally designed for four-wheel drive in this unit made it impossible for the chassis space to accommodate them all.

An enlarged or lengthened mechanism.

Corresponding Solution: Abandon the original four-wheel drive and switch to two-wheel drive with the front wheels...

Add two swivel casters. (See Figure 25 below)

Machine Translated by Google

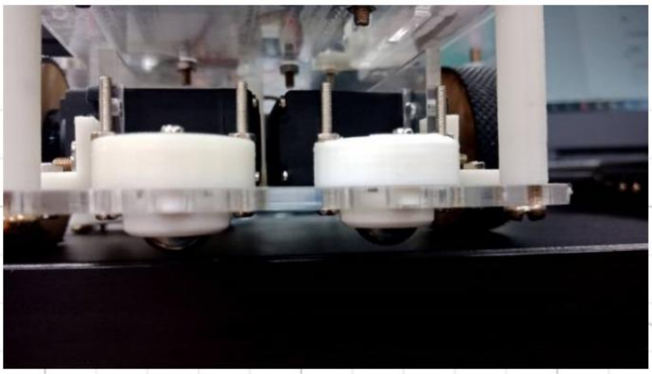


Figure 25. Front omnidirectional wheel

Problem 5. When the cam (ratchet) rotates, it will interact with the motor's mounting bracket, the connecting mounting bracket, and the base.

Interference from the L-shaped fastener on the disc.

Solution: Lower the height of the mounting bracket and L-shaped fastener so that the cam does not interfere with it.

(See Figure 26)

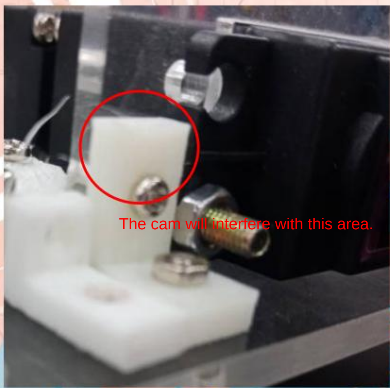


Figure 26. Improved mounting bracket and taller mounting bracket (from left to right)

Problem 6. When the chopsticks are used to fire, they will slide outward due to inertia because the grip is not tight enough.

Solution: Flatten the upper semicircular part of the original clamping element so that the chopsticks can be firmly clamped.

Hold. (As shown in Figure 27)

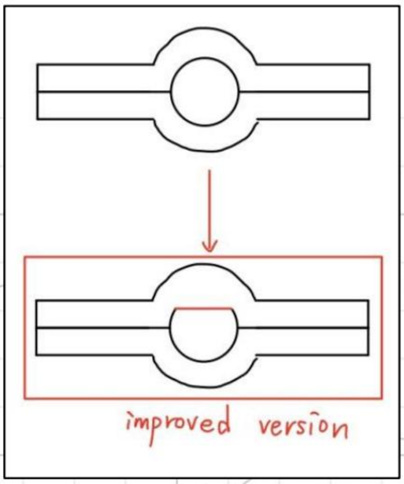


Figure 27. Improved clamping method (from bottom to top)

Part Two: Manufacturing

Problem 7.3D printing is limited by the precision of the machine, so the printed components may not match the actual components.

Errors in CAD files can cause sliding parts to get stuck and unable to move smoothly on the slide.

Solution: Adjust the CAD settings and allow for additional dimensions (as shown in Figure 28).

Figure 28 Comparison of slide grooves (the right side is the improved version)

Problem 8. The cam follower was manufactured using 3D printing, but its roughness was not considered during the design phase.

It was sufficient, but the material properties were not strong enough, so it broke once during assembly and once during actual testing. (See figure)

29)

Solution: Drill a 3mm hole at the original driven part position , insert a screw and tighten the nut.

Derivative Problem: It was found that the slider could not be pushed by the cam when it was rotated halfway, due to the slider...

This causes bending, diverting the displacement of the original linear motion to a downward bending, resulting in a change in the actual forward motion.

The stroke (the linear motion portion) is very small, and the inside of the hole, due to the slight tapping of the screw, rotates...

During the movement, there will be relative rotation between the screw and the cam, so the screw moves along the generated thread.

Movement exacerbates the beending.

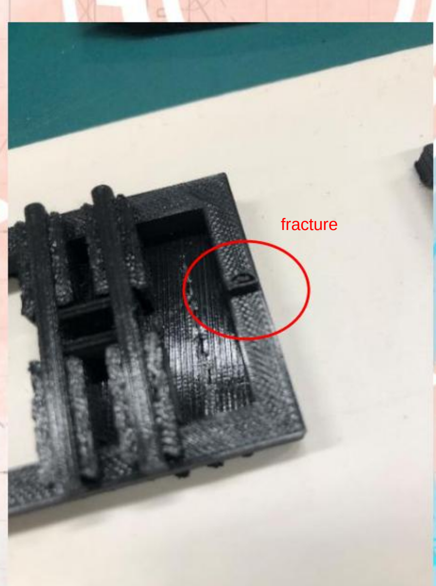
Corresponding Solution: Apply tape to the threads and tighten the nut to eliminate relative motion.

Derivative Problem 2: After implementing the above solutions, it was found that the slider still had bending.

It exists, presumably because the force is concentrated in one place.

Corresponding Solution: Add a U-shaped element to the slider to counteract this torque (e.g., ...

(Figure 30 below)



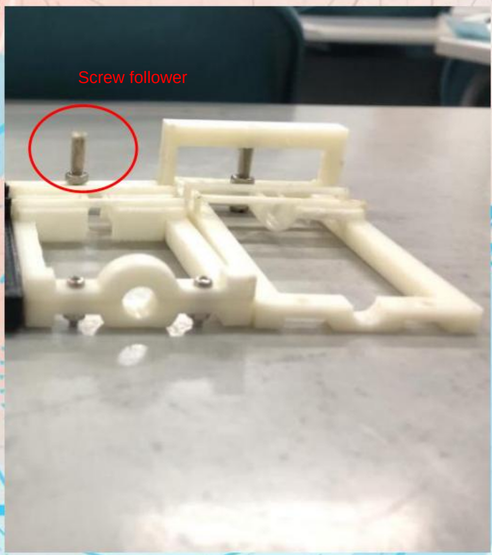


Figure 29. Fracture surface diagram of the driven component; Figure 30. M3 screw driven component, with an added "U" shape.

Improved slider (from left to right)

Problem 9. The support material for the printed document is difficult to disassemble. Initially, sandpaper and a file were used, but the accuracy was compromised.

The printouts are very low, and the printouts themselves are easily damaged.

Solution: Adjust the cable and then adjust the parameters to the appropriate level.

Part Three: Actual Testing (Because the problems encountered were only discovered the day before the competition or during the competition itself)

Therefore, only the possible causes of the problem and its solutions are presented.

Problem 10. When a billiard car runs on a billiard table, the right wheel moves slower than the left wheel, therefore the car will...

Turn right, because adjusting the parameters still couldn't solve the problem of different speeds, suggesting...

The cause of the accident was attributed to the "counterweight," and the excessive weight of the firing mechanism located at the rear caused it to contact the floor, resulting in...

The front omnidirectional wheel will be suspended in the air (because the vehicle body is tilted backward).

Solution: Use shims to make the rear firing mechanism level with the wheels, but this will prevent the billiard cart from reversing.

There might be vibration issues, so increasing the weight distribution at the front of the vehicle would be a more conservative solution.

Law.

Problem 11. The cam could not push the driven member during the actual test because it was pushing the driven member backward.

The cam can now rotate smoothly, suggesting the problem is due to insufficient motor torque, which prevents it from overshooting.

The frictional force caused by the downward bending of the firing mechanism against the chassis.

Solution: Replace with a new MG996 motor.

2. Design experience

First, we believe it's essential to clarify the purpose of this special report; we need to detonate a 50mm missile.

The marble is 35mm in diameter and weighs 1 gram, so you need to make sure the height of the chopsticks is the same as the center of the marble before proceeding.

Because this set uses a spring as the source of striking force, the bamboo chopsticks will retract during the retraction, thus...

To allow drivers to avoid having to drive the car within 10mm (1cm) of the marble...

For firing, we need a larger process, and the maximum process defined by this group is...

25mm means that the driver can hit the ball as long as the chopstick is within 25mm of the marble.

To accommodate the process size, we need a spring of suitable length and diameter, and its k...

The value should not be too large, otherwise the cam will not be able to push the follower, and the firing force will be too large.

In billiards, it may not be the optimal solution either.

Next, we need to design the mechanism we need. The firing mechanism used in this group is a cam.

Add a hollow box that allows the slider to move back and forth (as shown in Figure 31).

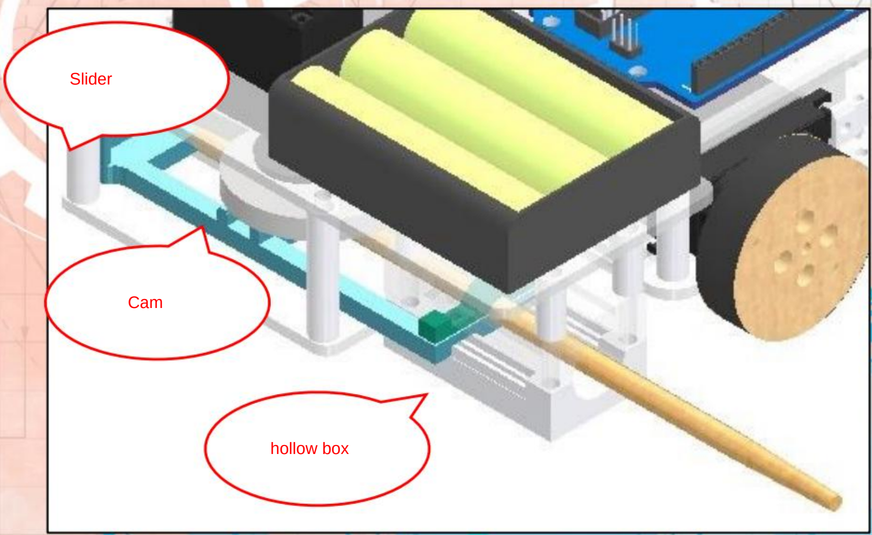


Figure 31. Schematic diagram of firing mechanism

This organization has encountered several problems: insufficient strength of the driven component, making it prone to breakage, and difficulty in removing 3D printed parts.

Issues such as the support materials for components, although we continuously address these through Agile (i.e., design changes, etc.)

(The iterative process of encountering problems, changing designs, and resolving problems) eliminates these problems one by one.

However, this mechanism has a difficult problem to solve: bending. When the cam pushes the slider...

When the screw on the driven part is tightened, the entire firing mechanism will bend downwards, and we choose...

Acrylic pads are used under the firing mechanism to help resist bending, but this also means that the sliding parts...

When retracting the rod, it presses down on the acrylic plate, shifting the original bending issue to...

Overcoming the sliding friction also means that the motor driving the cam needs sufficient torque.

The moment allows the cam to push the follower, a problem our group was unaware of before the actual measurement.

The existence of this factor meant that even if the driver practiced diligently for two days before the race, it was still too late to turn the tide.

VI. Meeting Minutes

09/22 (Tue)

1. Group Rules: A total of 10 group rules, covering punctuality, participation, production, and other related regulations.

Determining and assigning tasks.

2. Discussion of the first design sketch.

3. Obtain access to the practical training center

09/29 (Tue)

1. Continue the discussion on the first design sketch.

2. Propose a design concept and discuss its feasibility.

October 13 (Tuesday)

Midterm report discussion and presentation of PowerPoint slides

October 27 (Tuesday)

1. Due to manufacturing difficulties and various previously unconsidered factors, it was decided to replace the firing mechanism.

2. Decide to use a new firing mechanism and discuss its implementation and feasibility.

11/03 (Tue)

1. Complete the design of the firing mechanism.

2. Purchase some materials.

11/10 (Tuesday)

1. Cam mechanism testing and correction.

2.coding

11/17 (Tuesday)

1..coding

2. Purchase various types of springs, a total of 14 small springs, calculate their various values, and check if they meet the requirements.

need.

3. Due to the severe problems with the materials discovered last week, it was decided to remanufacture and reassemble the cam mechanism.

test.

11/24 (Tuesday)

1. Coding, assembling the motor, and testing.

2. Remote control adjustment

3. Complete the cam mechanism and discuss the chassis design and placement.

12/08 (Tuesday)

1. Manufacture and modify the chassis.

2. Trial assembly of the vehicle body and troubleshooting.

12/15 (Tuesday)

1. Assemble and test the first version of the car.

2. Correct the major overall problems.

12/22 (Tuesday)

1. Replace the materials of the vehicle body, reassemble the vehicle body, and produce a second version of the vehicle.

2. No major modifications will be made; only minor issues in each section will be addressed.

12/29 (Tuesday)

1/4 (Sun)

1. Fine-tuning

2. Strengthen the components.

1/6 (Tuesday)

1. Final calibration and test run.

2. Zhou Youlun has been chosen as the driver.

3. Prayer.

VII. References

1. Arduino Official Documentation:

https://www.arduino.cc/en/main/documentation

2. Shigleys Mechanical Engineering Design 10/e (2015)

3. Kinematics, Dynamics And Design Of Machinery 3/e (2016)

4. Microelectronic Circuits 7/e (2016)

5. Mechanics Of Materials 6th Edition