Design Document: Robocon 2025

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Contents

I. Introduction

The bots have been divided into several subsystems, each to complete the tasks while being compliant with the rulebook. We can roughly divide the bots into the following subsystems-

1) **Ball receiving mechanism:** The bots use a rotating pipes mechanism with a net attached between the pipes which are actuated by torsion springs and motors that help in winding and unwinding of the pipes. Normally, the pipes are folded down so that they fit within a cylinder of diameter 800mm and height of 1500mm. Once actuated, the pipes open, tightening the net and expanding the bot. A funnel is attached below this mechanism to direct the ball to the passing/shooting mechanism.
2) **Ball passing and shooting mechanism:** The bots use a flywheel-based mechanism to pass/shoot the ball. Just above the shooting mechanism, two servo motors hold and release the ball coming down from the funnel. The servo motors can be rotated to open or close the passage leading to the passing/shooting mechanism, giving the bot time to adjust the position and angle at which the ball is released from the passing/shooting mechanism. Additionally, a rotating curved surface is added in front of the shooting mechanism such that the angle at which the curved surface is placed determines the angle at which the ball leaves the bot.
3) **Dribbling mechanism:** The bots use a holder consisting of two fractions of a spherical shell to hold the ball. This holder can move up and down, open and close as well as rotate about an axis passing outside the spherical shell. The dribble is performed by throwing the ball up by moving the holder up, opening the holder so that the ball can go down and bounce back up, moving the holder down and closing it to catch the ball. Once the dribble has been performed, the holder moves up and rotates itself to put the ball into the funnel in the rotating mechanism.
4) **Jumping and dunking mechanism:** The bots have a plate attached to several springs, which are compressed using linear actuators using claws. To jump, the claws attached to the linear actuator hold the plate release, which results in the springs decompressing rapidly, and the plate is pushed against the court surface, pushing the bot up and causing it to jump. In the meantime, the holder used to dribble takes the ball and puts it into a bucket which then grips the ball using two spherical segment grippers . The arm then rotates and releases the ball when the bot performing dunk is mid-air.

II. Ball Receiving Mechanism

When the ball is aimed at the robot, the robot extends its arms to increase the capture area, accounting for any shooting errors. The arms act like pillars with a dual purpose: they increase the chances of receiving the ball and help deflect the opponent's attacks.

The robot has four arms along with a dunk arm, all four actuated by a single motor and a torsion spring. The torsion spring's rest position is when the arms are fully flexed. The arms close (align horizontally) using ropes driven by the motor. Each arm features grooves that ensure they align at the same vertical height when closed. The dimensions of the four arms are $650 \times 20 \times 20$ mm.

The robot is equipped with a dunking arm, which catapults the basketball into the basket. The dunking arm features two grippers that prevent the ball from falling out of the bucket during a dunk. The bucket of the

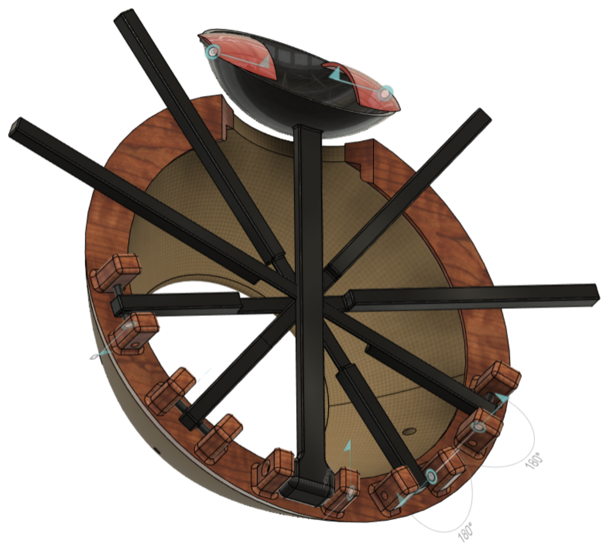

Fig. 1. Ball Receiving Mechanism

dunking arm is shaped like a spherical segment, designed to receive the ball from the dribbling mechanism before executing the dunk. The grippers are actuated by a servo motor, while the dunking arm itself is powered by a motor, ensuring a precise and controlled dunk. The dimensions of the arm are $650 \times 15 \times 30$ mm with a bucket attached to the arm inclined at $40°$.

The funnel has an opening of 440 mm at the top and 260 mm at the bottom with a parabolic shape that smoothens the ball's trajectory.

The dunking arm has a moment of inertia of $I = 0.244$ kg·m², a center of mass at $d = 0.4305$ m, and an angular acceleration of $\alpha = 3$ rad/s². The maximum torque required is calculated as:

$$T = I\alpha + mgd$$

$$T = (0.244 \times 3) + (1.87 \times 9.8 \times 0.4305) = 9.08 \text{ Nm}$$

Applying a factor of safety of 2, the required torque becomes:

$$T_{\text{required}} = 18.2 \text{ Nm}$$

For the closing arms, each arm has a moment of inertia of $I = 0.0135$ kg·m² and a center of mass at $d = 0.27884$ m. The maximum torque required is:

$$T = (0.0135 \times 3) + (0.372 \times 9.8 \times 0.27884) = 1.057 \text{ Nm}$$

With a safety factor of 1.5, the required torque becomes:

$$T_{\text{required}} = 1.59 \text{ Nm}$$

The torsion spring constant is calculated as:

$$k = \frac{1.59}{\frac{2\pi}{3}} = 0.77 \text{ Nm/rad}$$

Finally, the net torque required to close all four arms is:

$$T_{\text{net}} = 6.4 \text{ Nm}$$

III. Ball passing and shooting mechanism

The shooting mechanism consists of three parts- retainer, shooter and angle adjuster. Once the ball is received in the funnel, two servo motors are used to retain and release the ball into the shooting mechanism through a pipe. The two servo motors are either in open or closed position. When the servo motors are in a closed position, the ball doesn't have enough space to go into the pipe. The retainer mechanism gives the bot time to adjust

Fig. 2. Closed position

Fig. 3. Open position

parameters and orientation before passing or shooting the ball. Once the bot has adjusted its orientation and parameters, servo motors go into the open configuration, the ball is fed into the shooting mechanism through a pipe.

The shooting mechanism consists of two counter-rotating flywheels that accelerate the ball. Two flywheels with a diameter of 100mm and a mass of 1kg were used. Under the assumption that the bot is taking a shot

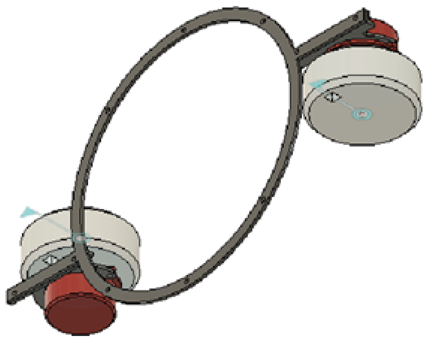

Fig. 4. Shooting mechanism

from half-line, there is no air resistance, and the vertical distance between the hoop and the point at which the ball is released is 1200mm, a projectile motion analysis has been performed. under the governing equations

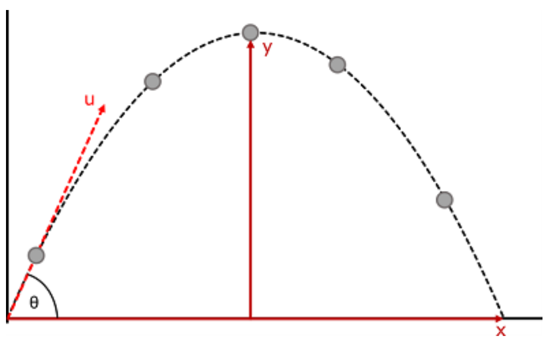

Fig. 5. Projectile motion analysis

$x(t) = ucos(\theta)t$ and $y(t) = usin(\theta)t - \frac{1}{2}gt^2$, we find $u \approx 10m/s$. Assuming no slippage between the flywheel and ball at the moment of release,

$$w_{final,\ flywheel} = \frac{v_{ball,\ release}}{r_{flywheel}},$$

$\therefore\ \omega_{final,\ flywheel} = 200rad/s$.

From conservation of energy,

$$2 \times \frac{1}{2} I_{flywheel}\omega_i^2 = 2 \times \frac{1}{2} I_{flywheel}\omega_f^2 + \frac{1}{2} m_{ball}u^2$$

$\omega_i = 260rad/s \approx 2500\ rpm$. Taking an additional factor of safety of 0.5, the motor used here must be capable of reaching 3250 rpm.

The angle adjuster mechanism consists of a section of a tube rotated using servo motors to adjust the angle at which the ball is released.

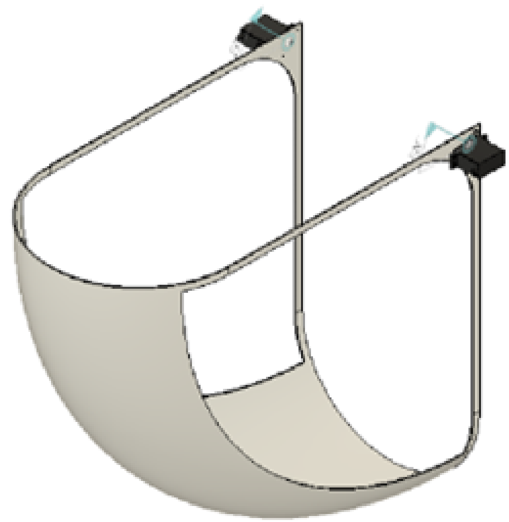

Fig. 6. Angle adjuster for Shooting Mechanism

IV. Dribbling Mechanism

After the ball is in the inner funnel, a motor will direct it to either the dribbling arm or the shooting arm. If the operator decides to dribble, the ball goes to the bowls of the dribbling mechanism.

The bowls are attached to a slider that is moved using a belt drive. The slider is accelerated upward, which also accelerates the bowls and the ball with it. At the top, the slider and the bowls are stopped, letting the ball upwards with some velocity.

The ball reaches the top point and starts to fall under gravity. While it is falling, the bowls are split open to let the ball pass through, so that it bounces on the ground. The slider is moved down, in a position to catch the ball.

After bouncing on the ground, the ball comes back up, above the minimum mark of 700mm (when the assumed coefficient of restitution is 0.77 between the ball and the court), after which the bowls are closed back and are moved up to the basketball, completing the dribble.

The ball is then deposited in the funnel at the top, from where we can decide whether to give it to the shooting mechanism or the dunking mechanism. The bowls then go back to their retracted position, keeping the total span of the bot within the limits of the rule book.

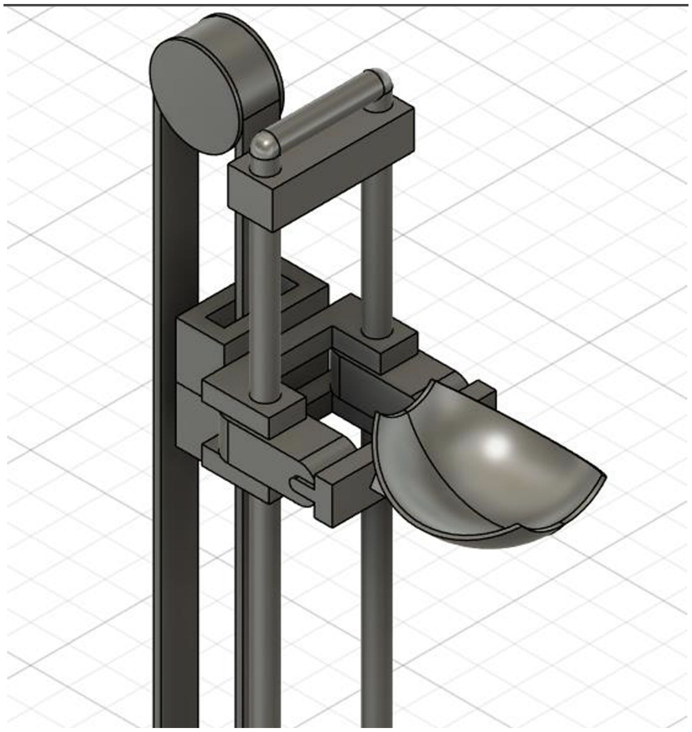

Fig. 7. Slider Attachment

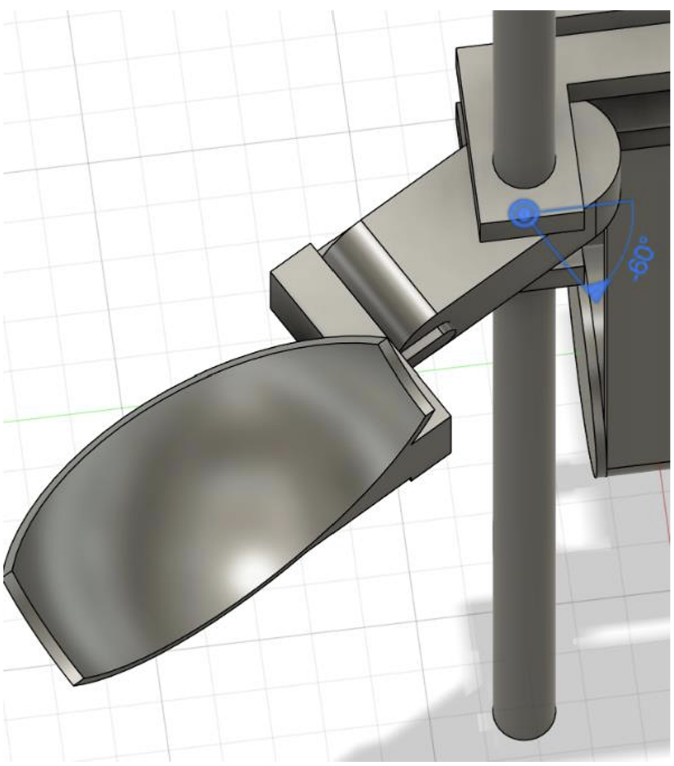

Fig. 8. Splitting the Bowls Apart

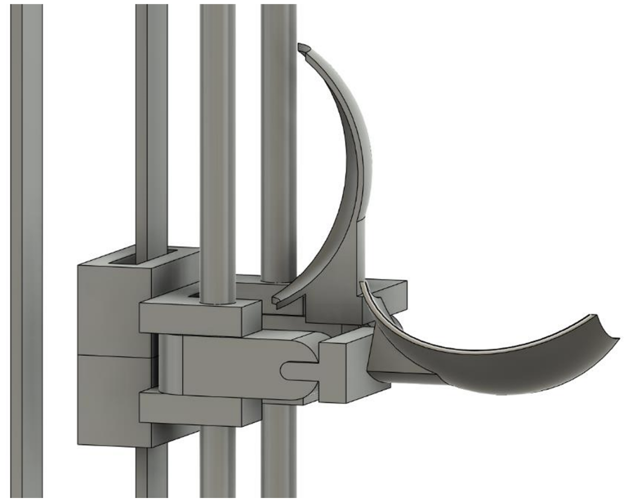

Fig. 9. Retracting the Bowls

V. Jumping mechanism

The configuration is the compressed state due to the own weight of the bots where the most weight will be above the disk. The above-mentioned mechanism will be present between the power train and the entire bot. The base plate will be attached to the power train.

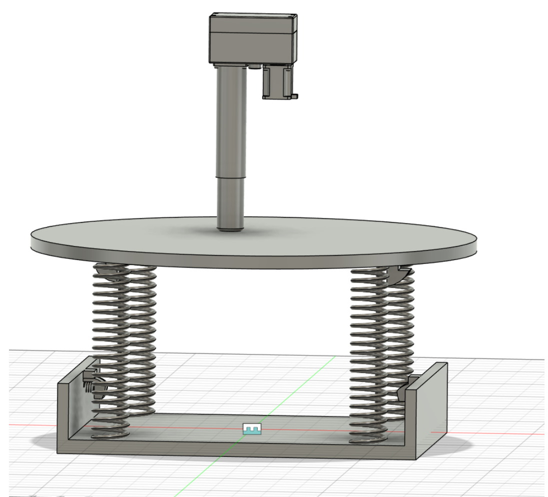

Fig. 10. Jumping mechanism(Compressed position due to its own weight)

When we need to dunk before the ball is received into the dunk arm, the springs are compressed with the help of a linear actuator based on the calculations mentioned below.

For 50 kg weight of the bot:

$k = 2000\,\mathrm{N/m}$

Height to be raised = $10\,\mathrm{cm} + 50\%(h) = 15\,\mathrm{cm}$

$kc = mg$, $c = \frac{mg}{k} = \frac{490}{2000} = 0.245\,\text{m} = 24.5\,\text{cm}$
Compression because of weight $(c) = 24.5\,\text{cm}$
$mgh = \frac{1}{2}kx^2$
$x = 28.45\,\text{cm}$ (for 4 springs placed parallel, each spring with $k = 500\,\text{N/m}$)
Here x is compression required to jump the mentioned height
Length of each spring $(l) = 60\,\text{cm}$
Force required to compress = $569\,\text{N}$

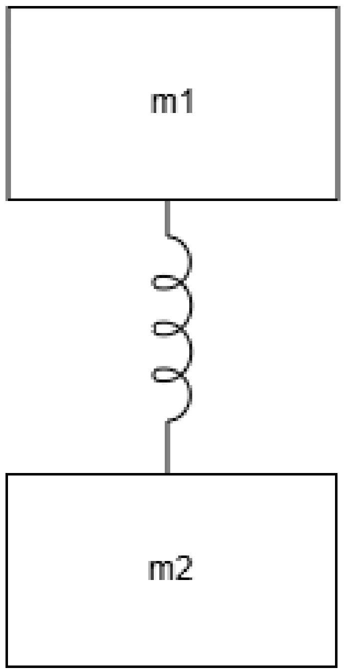

Fig. 11. 2 blocks and a spring

Considering extra mass to include losses
$m_1 = 50\,\text{kg}$
$m_2 = 5\,\text{kg}$ (power train)
By conservation of momentum when m_1 comes to the initial position where there is no net force,
$m_1 v_0 = (m_1 + m_2) v_1$
$v_0 = \sqrt{2gh} = 1.73\,\text{m/s}$
$v_1 = 1.574\,\text{m/s}$
Height risen by overall mass = $12.38\,\text{cm}$
Force required to compress the springs = $569\,\text{N}$
Time it will reach the max height = $0.4\,\text{s}$

Based on the calculations above:
Each spring should be compressed by $28.45\,\text{cm}$
After compressing, the springs should be locked in that position; hence, a locking mechanism is added.
When the top cylinder reaches the compression of $28.45\,\text{cm}$, the spring connected to the locking mechanism compresses and gets locked. A similar mechanism is also present on the opposite side.

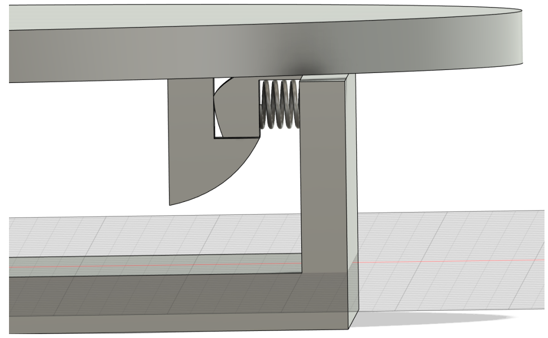

Fig. 12. Locked position after compression

So when we need to jump, we will compress the spring to release the lock, which will be done externally by a linear actuator connected to the lock.
As the COM is just above the circular plate as it moves up, the power train also moves up along the bot, and then the dunk will be done with the help of the dunk arm.