Robocon 2020
Design Report

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1.General Overview:

The Robocon 2020 problem statement is an exciting and nuanced challenge. After a variety of brainstorming sessions, simulations and testing, our team designed and tested the following strategies for the challenges posed by the Robocon 2020 rule book.

2. Solution Ideas:

2.1 Passing robot(PR)

A passing bot weighing 18 kgs having dimensions 900 x 900 x 1200 mm is driven by four planetary gear Cytron motors (model PG45ZY4524600) arranged in 4-wheel concentric holonomic base configuration. This design was chosen as the main base providing support to all the mechanisms. The wheels with their axes at 90^o to each other, were used in order to facilitate a holonomic drive. These wheels were chosen over Mecanum wheels as the former has reduced vibrations which results in a stable structure and prevents gradual loosening of fasteners. Plywood – 12mm thick, was chosen as the material of the base as it provides a large, continuous and rigid support.

The manual pass bot picks the try ball up with a gear claw arrangement and places the ball on the pneumatic two-prong mechanism. It has a catapult or paddle mechanism to propel the ball in the direction of the try bot.

2.1.1 Sensors and Actuators

Electronic actuators drive the four Omni wheels. Cytron IG45-33K was the motor of choice.

Pneumatic actuators were used to actuate the throwing arm. These are double-acting cylinders working under a range of pressures (4-6 bar).

Inertial measurement unit (IMU): Razor IMU 9250 features the latest 9-axis MEMS sensor from InvenSense. Its compact structure makes it versatile and convenient to use, providing greater onboard space for other components.

It is incorporated with a 16bit ADC that provides higher resolution and less margin for error. The razor IMU9250 plays a pivotal role in reducing mechanical inaccuracy by tallying IMU values with a proportional, integral, derivative (PID) algorithm

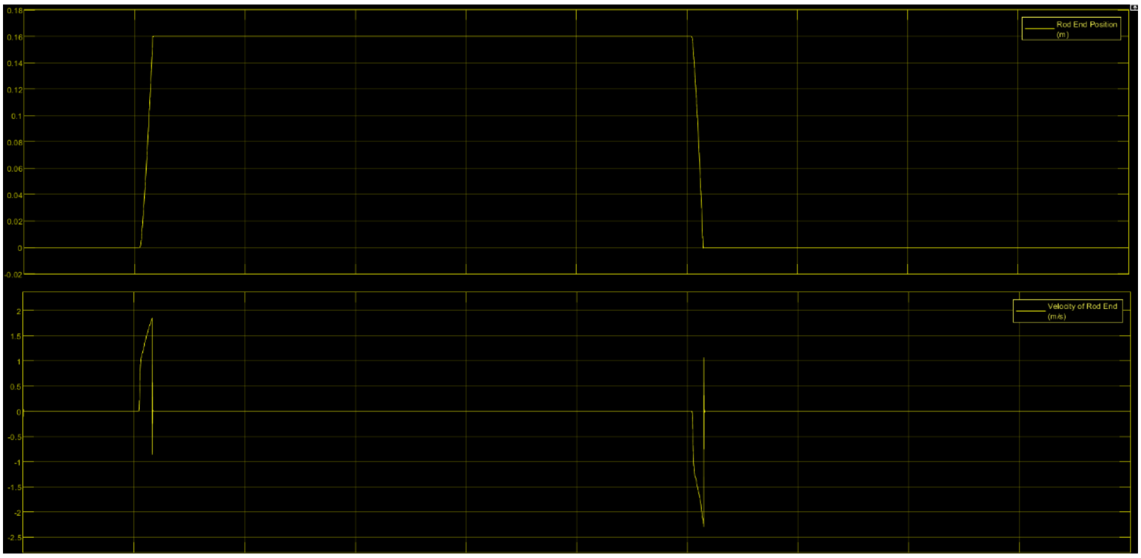
Relays: During the gameplay the 2 pneumatic pistons are actuated electronically via solenoid valves that are energized by a 24v supply through the relay modules. Relay modules have been used because they are highly robust and can handle large amounts of current.

2.1.2 Picking

In order to pick the ball from the ball rack, a mechanism had to be devised in order to transfer the ball from the rack to the passing catapult. After discussing multiple ideas, a gripping mechanism was devised. The gripper, is first actuated by a MG958 Metal Gear Servo, which drives a dual gear train, using spur gear meshing. These arms apply the necessary gripping force on the ball. The arms are mounted on a 3D-Printed coupler, which connects them to the revolving shaft. The coupler was required to bear the weight of the arms (150g) and the weight of the servo (55g). A Von Mises Stress Analysis on the part proved it to be well within safe stress limits (maximum 0.16Mpa). The motor to revolve the gripper was chosen based on torque calculations. The gripper, including the servo and the holder weighed 250g. While holding the ball, the entire mechanism weighed 510g. From this the torque on the motor was derived using the equation Torque = Force * Moment Arm. Thorough calculations resulted in a holding torque requirement of 5.8kg-cm. Accounting for a safety factor of 1.5, the final torque requirement was finalized at 8.7kg-cm. For accurate position control, stepper motor (NEMA23 10.1kg-cm Hybrid Stepper Motor) was chosen. This entire mechanism is then rotated about the shaft axis, by the stepper, and the ball is transferred onto the throwing catapult arm.

2.1.3 Passing (Throwing)

The passing mechanism is actuated pneumatically using a double acting cylinder (160mm stroke, 50mm bore, 10 bars rated pressure). The retraction of the cylinder rod creates a moment about a fixed point, which is located at a height of 480mm from the base, mimicking the movement of a catapult. This movement launches the ball, which is placed on the other end of the catapult arm. Simulation of the pneumatic cylinder was carried out in the SimScape Environment in MATLAB to obtain graphs of rod-end velocity v/s time and rod-end position v/s time. The rod-end attained a maximum velocity of 1.82 m/s at a pressure of 5 bar. From this, the velocity of the end effector of the catapult was derived. It was found that the cylinder provided a velocity of 6.83m/s to the end effector. Using kinematic equations for projectile motion, the range of ball obtained was 3.3m. This range influenced the height of the receiving mechanism.



velocity and position of end effector vs time

2.2 Try Robot (TR)

The TR has the receiving, placing and the kicking mechanisms on it. Dimensions: The TR is square in shape and has a maximum width of 800mm. After the extension of the leg the dimension increases to 800x1200mm. The height of the TR is 1140mm. A four-wheeled design was chosen as the main base providing support to all the mechanisms. Four wheeled bases have greater stability and can move faster. Four Omni wheels, axes at 90deg to each other, in a cross pattern, were used in order to facilitate a holonomic drive. The choice of material was once again 12mm thick plywood.

2.2.1 Actuator

Electronic actuators drive the four Omni wheels. Cytron IG45-33K was the motor of choice. Cytron IG45-14k was the motor used to rotate the tray for placing the ball in the try spot. Pneumatic actuators were used to actuate the throwing arm. These are double-acting cylinders working under a range of pressures (4-6 bar). Inertial measurement unit (IMU): Razor IMU 9250 features the latest 9-axis MEMS sensor from InvenSense. Its compact structure makes it versatile and convenient to use, providing greater onboard space for other components. It is incorporated with a 16bit ADC that provides higher resolution and less margin for error. The razor IMU9250 plays a pivotal role in reducing mechanical inaccuracy by tallying IMU values with a proportional, integral, derivative (PID) algorithm

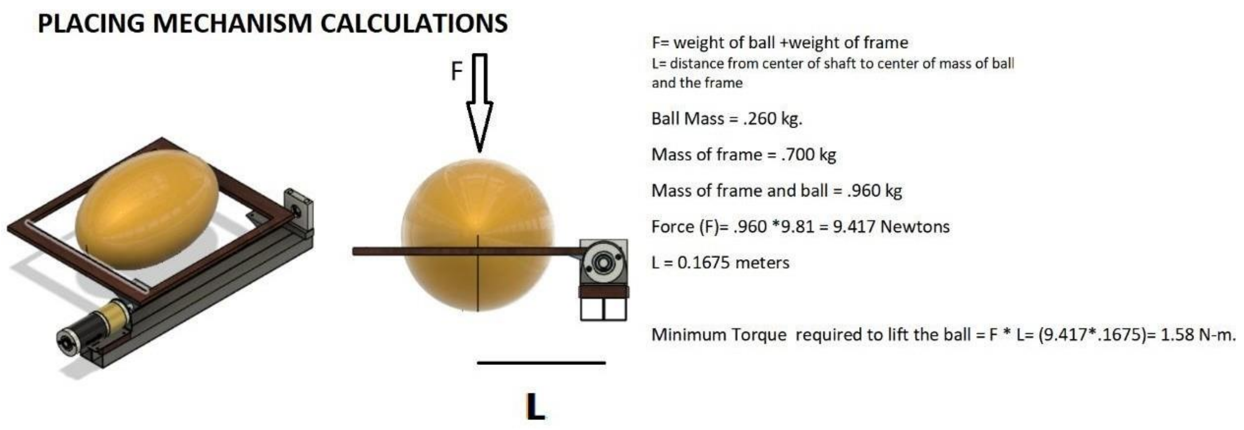
Relays: During the gameplay the 2 pneumatic pistons are actuated electronically via solenoid valves that are energized by a 24v supply through the relay modules. Relay modules have been used because they are highly robust and can handle large amounts of current.

2.2.2 Receiving

The ball follows a projectile trajectory, which is intercepted by a receiving mechanism. The receiving mechanism is a structure with a tapering profile that funnels the ball into the placing tray. The funnel is made of aluminum extrusions welded to provide maximum joint strength and minimize vibrations. Between each extrusion, is a fine metal mesh, preventing the ball from falling outside.

2.2.3 Placing

The placing tray is a compliant net made of synthetic fiber. This absorbs the shock of the ball falling into the tray from the receiving funnel. The entire tray is mounted on an axis driven by a Cytron IG45-14K motor. The motor has high torque, which successfully places or "touchdowns" the ball into the try spot. The motor was chosen based on a few torque calculations. The placing tray, without the ball, weighed 700g. The tray is made of wood, it holds the ball, falling from the receiving funnel. Once the ball has settled into the tray, the weight of the tray increases to 960g. This tray is rotated about an axis which is placed at 16.75cm from the center of mass of the tray. The required torque was calculated to be 15.8 kg-cm. The Cytron IG45-14K has a rated torque of 17.7kg-cm, which is ideal for this application. It also has sufficient RPM (148) to successfully place the ball without allowing it to touch the edges of the try spot.



2.3 Kicking

The ball is manually placed by one of the team members at the kicking spot. The kicking mechanism consists of a leg-like extrusion, with a free rotation axis at a height of 505mm from the base, actuated by a double acting pneumatic cylinder (250mm stroke, 32mm bore, 10 bar rated pressure). Upon extension of the cylinder rod, a moment action is created about the free rotation axis, propelling the leg towards the kick ball. With iterative testing of the kicking, it was observed that the addition of a triangular attachment at the bottom of the leg increased the height of the kick. The counterclockwise angle of the kicking surface of the attachment with the leg was varied during testing to increase maximum height attained by the kick ball during its flight. Projectile trajectories were plotted for multiple velocities ranging from 10m/s to 15m/s. (Graphs included). This gave us the required ranges.