Design Details Document

ROBO RUGBY 7s

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The "ROBO RUGBY 7s" is the game of two robots and five obstacles which acts as five defending players. As per the problem statement, the two robots collaborate to score Try and Goal Kick. With careful considerations and possibilities of various strategies, the kicking process is done by the Try Robot and the Kick Ball is manually placed. Both the robots are semi-autonomous, and there is well-built communication between both the robots to share their real-time position and the task they are performing. The mechanical design of the robots is compatible with both the arenas. Initially, both the Pass Robot (PR) and Try Robot (TR) are in their respective starting zones. As soon as the game starts, the PR travels towards the rack and picks up the first Try Ball using the devised mechanism. Meanwhile, the TR travels in the receiving zone; once the TR reaches the expected position to receive the Try Ball, it signals the PR to pass the Try Ball. On a successful receive of the Try Ball, TR travels to a given Try Spot avoiding the defenders using a Path Planning Algorithm. Further, TR places the Try Ball in the Try Spot. Now after a successful Try, a team member places a Kick Ball and Tee in the Kicking Zone. After placing Kick Ball and Tee, the TR proceeds to kick the Kick Ball.

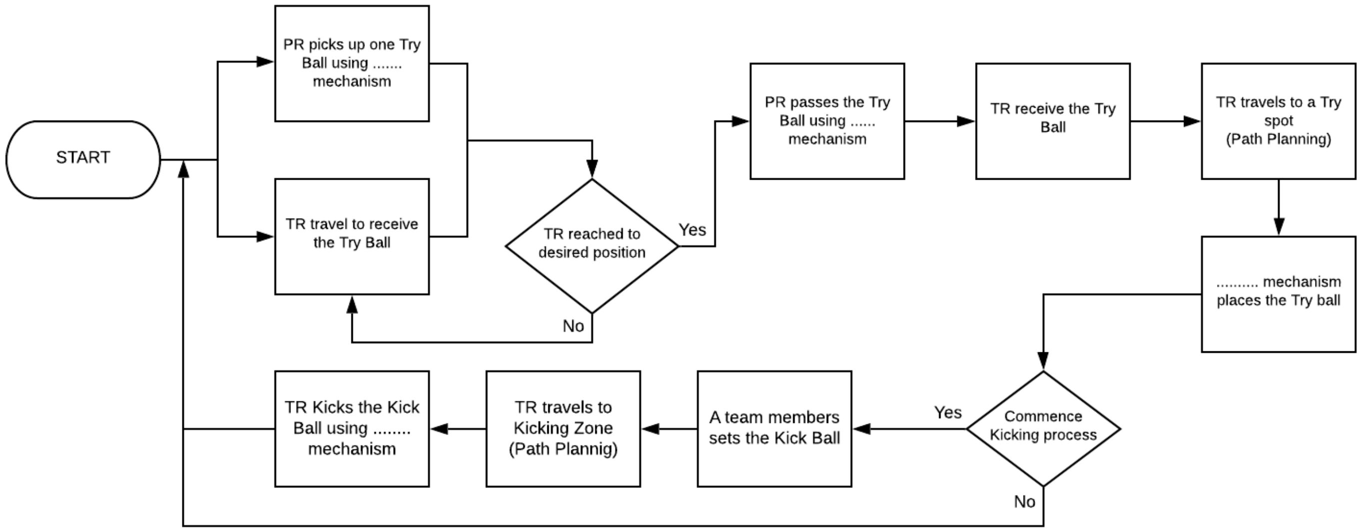

Figure 1: Game Flow

1 System Architecture

Robots being semi-autonomous, require a reliable system and feedback from various sensors. The system consists of multiple modules comprising microcontrollers and numerous sensors. The flow of data between different modules is shown in the Figure 2.

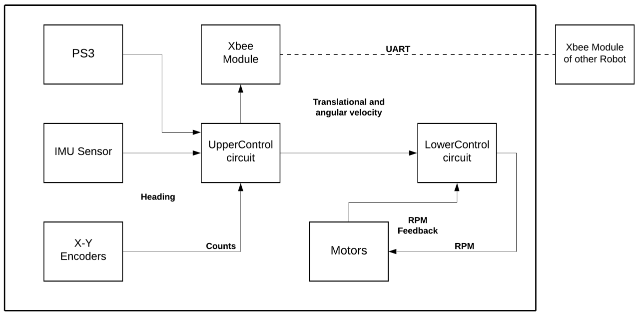

Figure 2: System Architecture

- UpperControl is the primary module that controls the flow of data and connects all the other modules.
- The IMU sensor calculates the current heading of the robot relative to the initial orientation and transfers it to the UpperControl.
- UpperControl fuses the data of IMU sensor and X-Y encoders to calculate the current position of the robot. Depending on the current position and heading, the UpperControl calculates the desired translational and angular velocities and sends it to the LowerControl.
- Using the Inverse kinematics model, the LowerControl calculates the angular velocity of each wheel required to achieve the desired translational and angular velocities of the robot.
- Collaboration is established between both the robots using the Xbee module.
- For manual control, a wireless Bluetooth PS3 controller is used.

2 Drive

A three-wheeled omnidirectional drive is used for both the robots as it provides smooth and well-controlled motion in any direction.

2.1 Autonomous

2.1.1 Local Localisation

The robot is localised using wheeled odometry, consisting of two 1000 ppr optical Rotary Encoders and an IMU sensor. The rotary encoders are hinged at the bottom of the chassis and are mutually perpendicular to each other. These encoders are coupled to 58mm diameter omni-wheels.

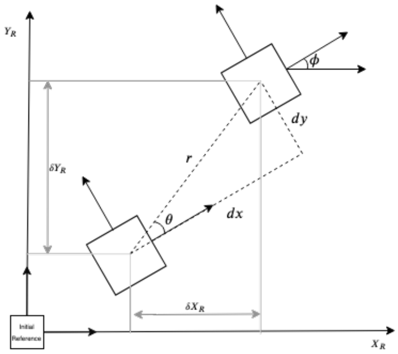

Figure 3: Localisation

Here, dx and dy are the small distance traversed by the robot w.r.t its own axis. dx and dy are calculated by using feedback of the two mutually perpendicular encoders. ϕ is the heading of the robot; δX_R and δY_R represents the resulting displacement of the robot w.r.t the axis of arena.

$$r = \sqrt{dx^2 + dy^2}$$
$$\theta = \tan^{-1} \tfrac{dy}{dx}$$
$$\delta X_R = r \times \cos(\theta + \phi)$$
$$\delta Y_R = r \times \sin(\theta + \phi)$$

2.1.2 Path Planning

The Try robot needs to plan it's path to reach a given point avoiding five obstacles. For this, a planning algorithm is developed using Pose and given Arena, which is inspired by Bug 2 algorithm. Suppose the robot is a circle of radius r. In accordance with the given work-space, the configuration space can be determined using the C-space transform as shown in figure 5.

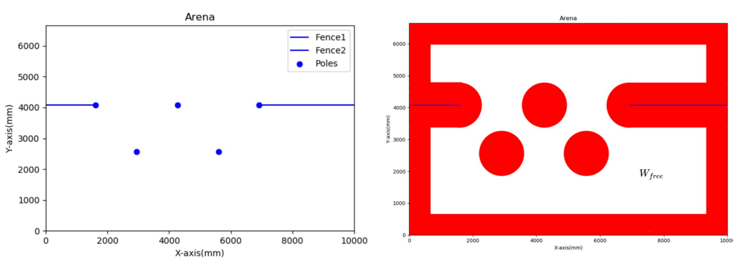

Figure 5: C - Transform

Let a goal position be assigned to the robot. Using the goal position and the current position, a rectangular window is generated. The enlarged poles contained in the rectangular window are then checked if they thwart the path of the robot, refer figure 6. Once this process is completed, the robot executes a straight line motion to the tangential point(T_i) of the first enlarged pole(O_i). The robot on hitting the tangential point(T_i) checks if the current enlarged pole thwarts its path(current to goal). If yes, the robot will circumnavigate the enlarged pole and leave at (L_i) when the enlarged pole no longer thwarts the path(current to goal). This process is repeated until all the enlarged poles thwarting its path are avoided. Note: Special cases for the fence are added.

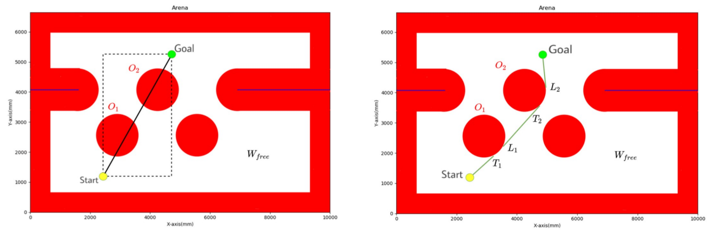

Figure 6: Planning the Path

2.2 Manual

Human assistance is necessary to complete many tasks throughout the game, and in case of erroneous behaviour shown by the robot while being autonomously controlled, the robots can be switched to manual control. For controlling the direction, speed, and orientation of the robot a Bluetooth PS3 controller is used.

2.3 Inverse Kinematics

An inverse kinematics model is implemented to control the motion of the robots with three-wheeled omnidrive. This model converts the desired translational and angular velocity of the robot into the angular velocity and turn direction of each wheel. A separate micro-controller processes the inverse Kinematics calculations and the desired RPM of the wheel is maintained using a PID controller.

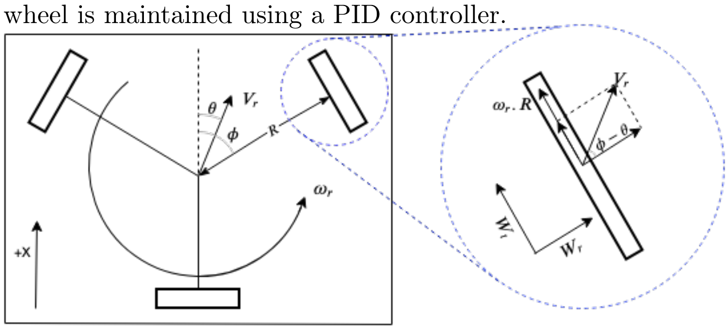

Figure 7: Inverse Kinematics

R is the radius of Omni-Drive. r is the radius of the OmniWheel. V_r and ω_r represents translational and angular velocity of the robot respectively. ϕ and θ are the angle made with +X axis by the axis of the OmniWheel and by the velocity of the robot respectively. W_t and W_r represents the translational and roller velocity of the Omni Wheel respectively.

$$W_r = V_r \cos(\phi - \theta)$$
$$W_t = V_r \sin(\phi - \theta) + \omega_r R$$

$$RPM = \frac{W_t}{2} \times 60$$

2.4 Collaboration

Establishment of proper communication between both the robots is very important. This is accomplished by using the Xbee module which works on the Zigbee protocol. It transfer data over long ranges without any loss. The data that circulates between the robots comprises of their current position and the task they are performing.

3 Pass Robot

- The stability of the robot is of prime importance; hence the centre of gravity is maintained close to the ground so that toppling of the robot is avoided.

3.1 Picking the Try Ball

The PR requires a precise mechanism that loads the Try Ball in throwing mechanism, which is 230 mm above the ground. The picking mechanism consists of a gripper and parallelogram linkage. The PR moves along the Rack until the Proximity sensor mounted on the gripper detects the Try Ball. A specially designed gripper consisting of one movable jaw, is then actuated using a high torque Vega motor to grip the Try Ball. This unique design of jaw consists of two angles, which gives a firm grip on the Try ball and prevents it from falling. For picking up the Try Ball, the Double Rocker mechanism is used whose design is based on the special case of Grasshof's Theorem (Parallelogram Linkage). The coupler link of this mechanism remains horizontal that retains the orientation of the Try Ball, which is the desired orientation for the throwing mechanism. Rocker is then actuated with the help of a pneumatic linear actuator. The bore diameter of the pneumatic linear actuator is based on the combined weight of gripper and ball, and the stroke length is determined on arc length required to load the Try Ball. After picking the Try Ball to the desired position, the Gripper drops the Try Ball in the bowl shaped structure of the throwing mechanism.

Pneumatic linear actuator for actuation of Rocker :

Bore Diameter	25 mm
Stroke Length	100 mm

3.2 Throwing Mechanism

Another task of the PR is to pass the Try Ball to the TR from passing zone to the receiving zone, which is about 4 m long. The mechanism is selected such that it is capable of throwing the Try Ball with minimum air consumption resulting in the maximum number of throws. It is based on a class three lever system; in which Try Ball is the load, the fulcrum is the pivot, and effort is a force applied by the pneumatic linear actuator. A quick exhaust is used to increase the forward stroke of the piston, which results in effective throwing of the Try Ball. Once the Try Ball is loaded in the bowl-shaped structure of the throwing mechanism, PR autonomously moves to the predefined position in the passing zone. A control signal from the TR is awaited to actuate the throwing mechanism.

Pneumatic linear actuator for Throwing Try Ball :

Bore Diameter	32 mm
Stroke Length	100 mm

3.3 Mounting of mechanisms

Picking and Throwing mechanisms are mounted sideways to grip the fifth Try Ball very easily, this technique/method of mounting the Picking mechanism reduces the further actuation which would be needed to slide the whole setup to grip the last Try Ball. As the Arena is not diagonally symmetric, so to make robot versatile for both the Arena, the only thing is to do is just rotate the base frame of mechanisms 180 and mount it on the chassis.

4 Try Robot

4.1 Kicking Mechanism

Another task of the Try Robot is to kick the Kick Ball from KZ3 to the conversion post of height 1.5 m and is 9 m away. The kicking mechanism is built-in aesthetically pleasing humanoid leg form so that it could mimic the motions of a human kicker preparing to kick. The upper and lower parts of the kicking leg of the robot are moved using pneumatic cylinders which are actuated at different time span. The upper cylinder is equivalent to the rectus abdominus muscle, and the lower cylinder is equivalent to the quadriceps muscle so that mechanism can mimic the motion of a human kicker drawing his leg back and kicking while moving the upper and lower leg simultaneously. The rectus abdominus air cylinder and the quadriceps air cylinder has a bore diameter of 40 mm and 32 mm respectively. The shoe is fabricated using wood which is tightened with the links of the kicking leg so that energy loss would be less.