

Problem

When it comes to any sport, people typically like to practice certain skills over and over in order to better master them. One such skill that people like to practice is shooting a basketball from different spots on the court. However, anyone who has done this has definitely come across the issue of having to run back and forth retrieving their ball after taking each shot. This results in more time running for the ball than actually shooting it.

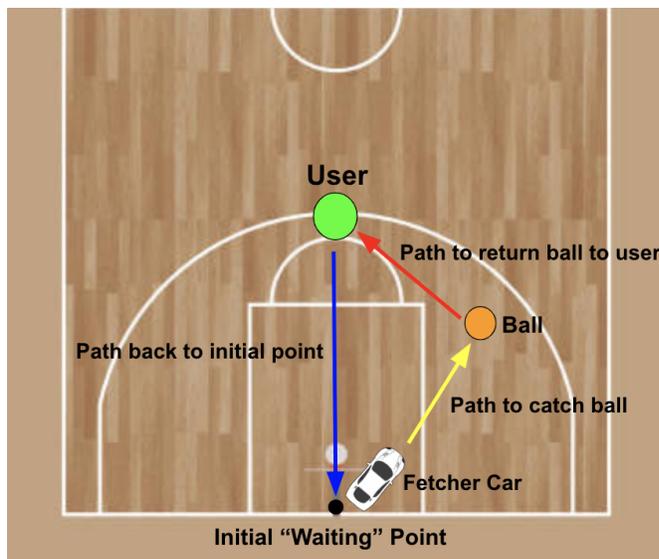
Solution

Our solution to this problem is a car that uses pincers to keep a spare ball or fetch a ball for the user. The user will be wearing APRIL tags so that the car can identify them. The ball will be spray-painted to be a distinguishable color so that the car can identify it.

The identification software will be on a Raspberry Pi and a PCB, which will control a 4WD car for movement and pincers attached to the front for grabbing/holding a ball. Control commands will be issued based on inputs from a camera and an ultrasonic sensor.

The car will use a camera to identify the ball, the user, and the waypoint from which it will wait for a ball to fetch. The car will start to fetch a ball if it is detected below a user-specified threshold in the camera view. When the car is close enough to a ball, it will use the front-facing ultrasonic sensor to determine when the pincers should be closed in order to grab the ball.

Visual aid

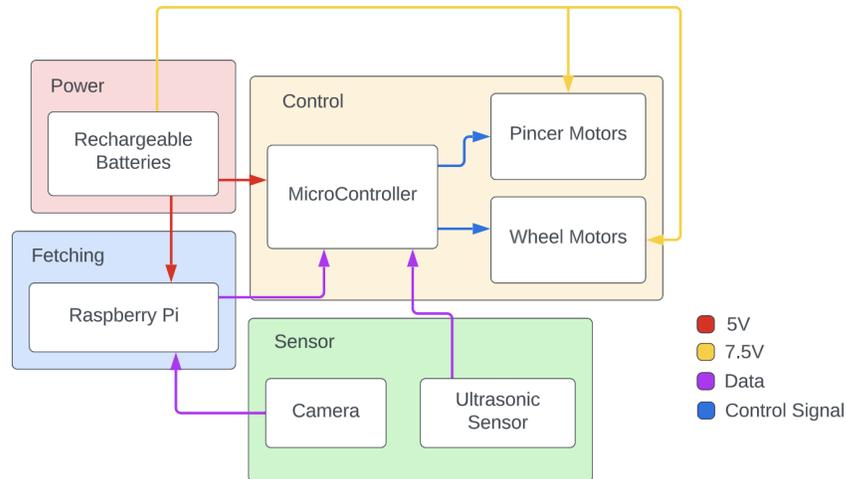


High-level requirements

- The car can identify and safely travel to the player and the designated waiting location within 10 seconds of beginning the search
- The car can maintain a distance of at least 2 meters from the ball until it becomes capturable.

- The car can capture and return a ball to the user within 30 seconds of the ball becoming capturable by the car

Block diagram



Subsystem overview

Power subsystem

This subsystem will be responsible for providing and regulating a power output to all of the other subsystems. Particularly, it will need to power the PCB and motors from the control unit, the Raspberry Pi from the fetching unit, and the ultrasonic sensors from the sensor unit.

Control subsystem

The control system will be responsible for driving the motors based on input from the fetching subsystem. Specifically, based on the position of the ball relative to the car, different motors will be powered so that the car can turn and drive forward till it reaches the ball. Additionally, signals will also be sent to the motors in the same manner so that the car can return the ball back to the user.

Sensor subsystem

A camera will be used to identify the user's position, the position of the designated waypoint, and the ball. When acquiring a ball, the ultrasonic sensors will be used to determine when the car's pincers should be closed. APRIL tags will be used to mark the locations of both the user and the designated waiting location. The ball will be a distinct color so that it can be easily detected and tracked with the front facing camera. Meanwhile, a rear camera will be reserved for use when the car has acquired a ball and needs to either return to its waiting point or return the ball to the user.

Fetching subsystem

This subsystem will constitute the majority of the software component of this design. It will take inputs from the power and sensor subsystems, which will be used to execute a sequence consisting of 3 major steps:

1. Wait at a designated location to watch for dropped balls to fetch.
2. When a fetchable ball has been detected, perform one of two actions:

- a. If the car is holding a ball, then it will first give that ball to the user before attempting to acquire the detected ball
 - b. Otherwise, the car will immediately attempt to acquire the detected ball
3. Once the ball has been acquired, perform one of two actions:
 - a. If the car gave a ball to the user in step 2, immediately return to the designated waiting location in step 1.
 - b. Otherwise, give the ball to the user and return to the designated location.

Subsystem requirements

Power subsystem

This subsystem will consist of several batteries hooked up to the Raspberry Pi, the motors, and the PCB. It will be responsible for ensuring that our car will be able to travel quickly enough to satisfy the time constraints for our design and ensure an acceptable battery life. The batteries attached to the motors must be able to supply 7.5V +/- 1V to motors so that they can be strong enough to move at acceptable speeds when holding a ball. The battery for the Raspberry Pi must be able to supply a constant current of at least 3.0A at 5.1V in order to power both the fetching subsystem and the cameras. The battery powering the PCB will need to provide 10A at 5V +/- 0.5V in order to power the ultrasonic sensors and enable communication with the motors and the Raspberry Pi.

Control subsystem

This subsystem will consist of the 4 motors for the wheels, 2 motors for the pincers, and the PCB. It will be responsible for ensuring that the car is capable of controlling its movement according to data from the cameras and sensors with the objective of acquiring a dropped ball. We will test the wheels by applying voltages individually to each motor to ensure that they are operating correctly and then also send signals to ensure that the motors can spin both forwards and backwards. If the wheels work on their own, we will test to see if we can make them move in unison and then finally send signals to see if the car can turn.

The pincers will be tested in a similar manner. We simply need to apply a voltage to the motors connected to them and ensure that they can spin both ways (to open and close the pincers).

Sensor subsystem

The sensor subsystem will be composed of an ultrasonic sensor and a camera. The ultrasonic sensor has to be able to pick up readings within a few centimeters away with a tolerance of a few millimeters so that the pincers can enclose the ball with no issue. We want to make sure that the ball is enclosed and not held by the pincers to minimize the friction the ball would cause (if the ball is rolling, it causes less friction than if it were to be held in a static position). Our camera will be required to send a constant feed to the fetching system (in particular, to the raspberry pi). The FPS of this feed does not need to be high as we only need it to be able to identify the ball and keep it relatively centered (we estimate that the FPS will not need to be higher than 10).

The ultrasonic sensor can be tested by moving objects near it and seeing the resulting signal that it sends (we can record expected values so that we can test to see if the sensor is consistently sending the same signals every time we test it).

The camera can be tested by looking at a few frames of the feed and making sure that they aren't distorted. We can then test to see if the camera is able to send a constant feed at the FPS

of our choice for a few seconds (record an estimated amount for a given time frame and make sure that the tests are consistent with it).

Fetching subsystem

This subsystem will exist entirely on the Raspberry Pi. It will be responsible for tracking/monitoring objectives (ball, player, waiting zone) from a distance with the cameras from the sensor unit. It will also receive input from the ultrasonic sensors which will be used to send instructions to the control unit regarding when to release a ball, acquire a ball, or move the wheels in a certain configuration.

Case where the project fails to work

At the end of our project we expect to have a fully functional car that can track down a basketball and return it to the user. However, once assembled completely, if the car isn't fully functional, there are certain components that we still expect to work properly regardless of the state of the car.

For one, we expect our camera to be able to process an image of a basketball court and track down any basketballs in the frame. That is, if we were to set up a camera on the court, we anticipate that it will be able to find the ball as it is thrown and as it moves around the court. This can be demonstrated by displaying an indicator on the ball in a given frame from the camera. Another component that we would expect to work on its own is the ultrasonic sensor. The purpose for the sensor is to detect when the ball is within the range of the pincers so that they could be activated. We should be able to simulate this behavior by placing an object close enough to the sensor and demonstrating the resulting signal that the microcontroller would send to the pincers.

Tolerance analysis

With a minimum voltage of 6V, the motors on the car can carry a maximum weight of about 0.6kg. This means that we have to take the weight of our components into careful consideration. One approach to overcoming this issue would be to ask if the pincer attachment for the car could have 2 extra motors of the same kind attached to it in addition to the actuator. Assuming that each motor applies enough force to move a 0.15kg load, this would increase the maximum load weight to 0.9kg. In the event that a 0.9kg capacity is still not enough, another option would be to use a lighter ball, such as a volleyball, for testing. The second option wouldn't improve the capacity of the car, but it would make it possible to maintain acceptable speeds with more weight on the car itself. The third option is to use the motors at or near their highest voltage of 9V. Assuming that 1V is enough power for the motors to move 0.1kg, this would increase the capacity to 0.9kg. Combined with the first solution, we could increase the weight capacity of the car up to 1.1kg. In the event that all of the above options are not enough, we will have to find more powerful motors and adjust our power subsystem accordingly.

Ethics and safety

The ethical issue of maintaining and improving our technical competence and undertaking technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations will, without a doubt, be the issue faced the most often by our group throughout the duration of our time working on this project. Since our experiences with working

on a design project of this kind are limited, we will have to make sure that work is assigned to each individual in our group according to any experience or desire to learn that they might have. However, this will make it the responsibility of each individual in the group to clearly state the limitations of their experience, knowledge, or other factors that would contribute to completion of the project before the due date.