Golf Robot (Project 11217)

Multi-Disciplinary Senior Design

Rochester Institute of Technology

Introduction

Augmented Reality (AR) games are gaining popularity these days as players experience a greater level of fun and adventure. David Schwartz and Jessica Bayliss at the Department of Interactive Games and Media at RIT initiated this project to enhance their previously existing Virtual Golf Project. In the previous project, the golf ball was placed on the green using a huge metal leverage which interfered with the player's experience and the ball was not placed accurately in the specified location. In this Golf Project, the use of a robot to place a golf ball would enhance player experience immensely. The robot will have physical appeal, be landscape friendly, be interactive and move accurately to a specific location within an acceptable margin of error. In order to deliver these goals, the robot must be able to wirelessly communicate with a PC at a distance of at least 100 feet for the purposes of receiving target coordinates and sending a 'task completed' signal during each round. It should navigate to the received coordinates with a margin of error less than 2 feet. It should carry and drop a golf ball at the target coordinates while causing no visible damage to the green.

In order to achieve the goals mentioned above, the project was divided into six main categories: chassis design, ball placement mechanism, sensor calibration, camera development, software and communications.

Motor and Gearbox Selection

The major mechanical components are the motors and gearboxes, which have a direct connection to the shaft that the wheel is attached to. This means that the only gear reduction of the motor is done with the gearbox; the wheel size offers some contribution force at the wheel contact points and the rate of speed.

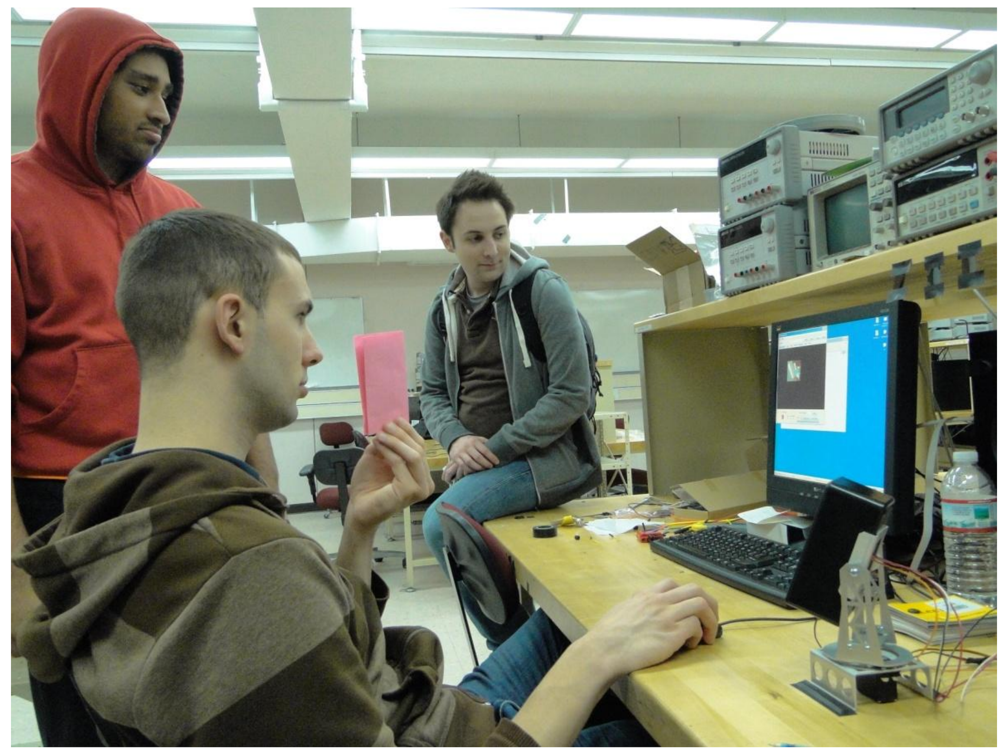
Before moving into motor analysis and calculations there are predetermined constants that need to be taken into account. These constants include an 8" diameter wheel size to allow for appropriate clearance of the golf ball while it is on the ground. The weight of the robot was decided to be a maximum of fifty pounds to help allow users to easily move the robot and to not tear up the grass on the surface of the green. The final constant was the maximum movement speed, which is one foot per second; this value was decided upon since it is relatively slow but can still be easily controlled.

To be able to efficiently use the robot's battery and get the most out of a motor it must be operating efficiently. For most permanent magnet DC motors this means the motor should almost always be operating above the 60% efficiency mark. The motor which was chosen operates anywhere between 12,500 RPMs and 7,500 RPMs when it is operating at above 60% efficiency, with it operating most efficiency at about 11,500 RPMs. Given the chosen wheel size the robot needs to have about 28 RPMs to move at around 1 foot per second. If this is divided into the RPMs at the most efficient point, 11,500 RPMs, a ratio of 410:1 obtained. The gearboxes and motors are coming from Banebots, which in this type of transmission only offers the highest ratio of 256:1. With this ratio, the motor only needs to operate at about 7,100 RPMs. This is just outside the efficiency range, therefore given the options and the excess torque that will be available this was determined to be sufficient.

With the selection of the 256:1 gearbox this will allow the robot to move at a rate of speed almost double than that of what was originally defined, this is of course assuming absolutely no parasitic loss.

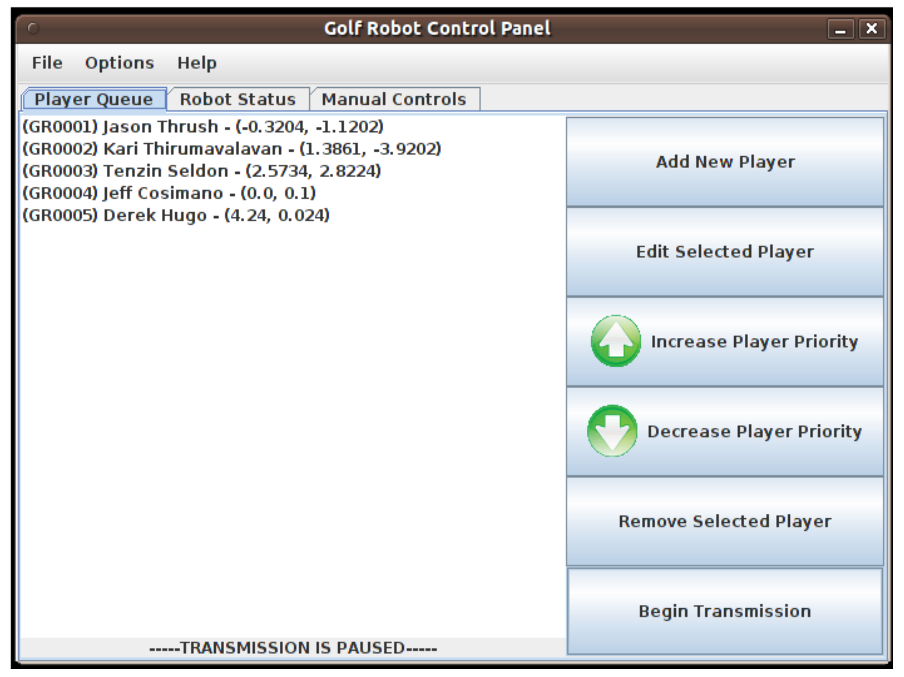
Ball Placement Mechanism

The purpose of the Ball Placement Mechanism (BPM) is to hold the golf ball while the robot navigates to the given coordinates. The BPM can be broken down into two main components: the emitter/phototransistor pair and the servo with the carrier arm. The emitter circuitry produces a 40 kHz signal, which the phototransistor recognizes. The output at the phototransistor will produce a high (~5V) if a golf ball is present (blocking the signal from reaching the phototransistor) and a low (~0V) if there is no golf ball present.

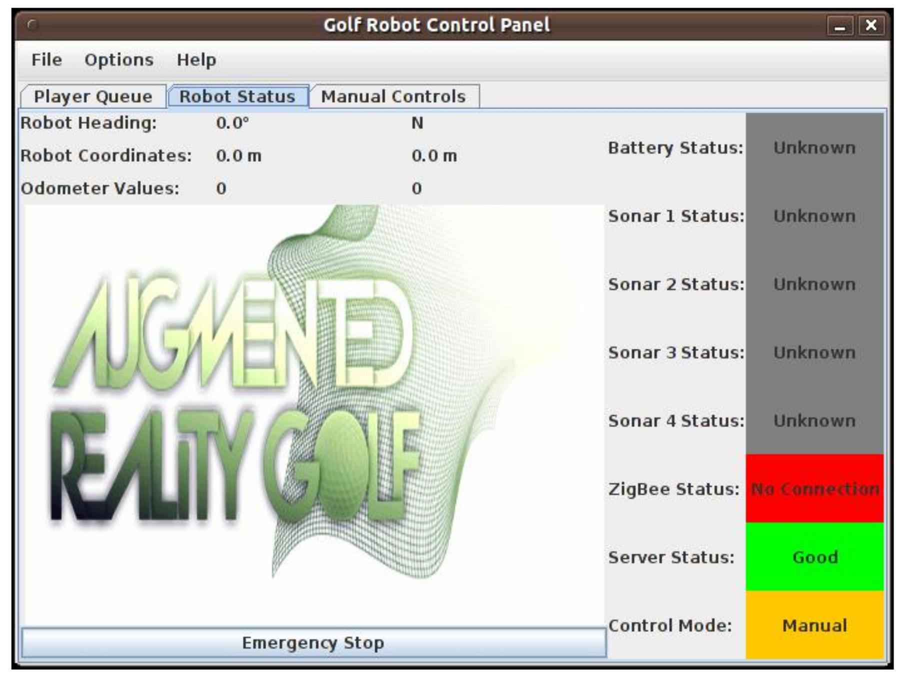


Communication

The Golf Robot communicates with the AR Golf simulator software via a laptop relay and an XBee radio channel. As players complete the simulator portion of the game, the simulator determines the location of their golf ball on the green and uploads those coordinates to a web server.



A Golf Robot Control Program (GRCP), meanwhile, runs on a laptop stationed next to the golf green. The program periodically requests new coordinates from the server and stores the coordinates in a queue. The coordinate pairs are automatically transmitted to the Golf Robot as needed. The GRCP also displays aspects of the robot's health and allows the operator to add, edit, and remove players in the queue. For typical play, however, the laptop software requires minimal interaction with the operator once initiated.



The RIT Wi-Fi has been tested around the green and has shown adequate ability to send and receive Wi-Fi packets (test showed signal strength of about 40%). The range and data rate of both the XBee transmitter (300 ft, 250 kbps) and RIT Wi-Fi (~50 Mbps) are sufficient for our application. The XBee channel has also been extensively tested under different conditions.

Sensors

The AR Golf Robot uses sensors to help navigate and maneuver on the green of the golf course. The two sensors utilized are the ultrasonic range finder – Maxbotix LV EZ1, and the Honeywell Digital Compass – HMC6352. The ultrasonic range finder is used to make sure that the golf robot does not crash into any object in its path. The compass is used to help orient the robot so it may deliver the golf ball to the next coordinate accurately as possible.

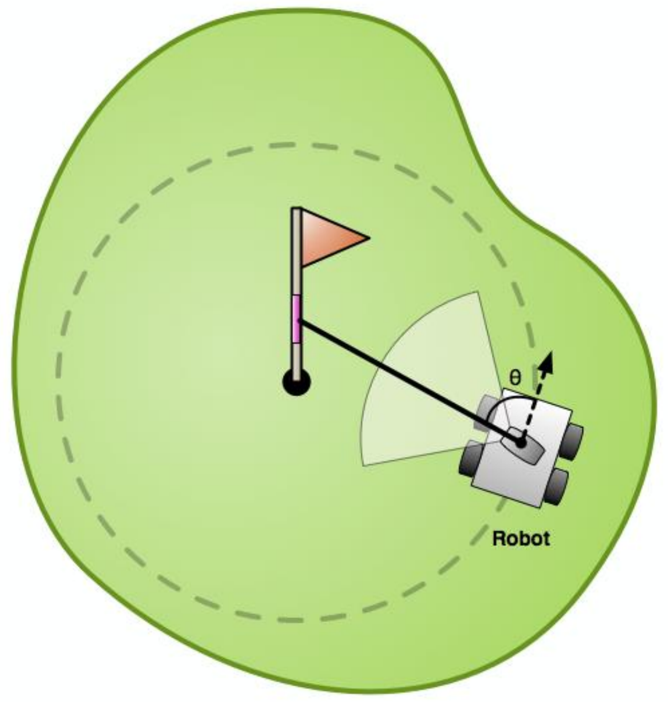
The Maxbotix LV EZ1 helps to ensure object avoidance is achievable by the golf robot. This sensor uses sound to determine that there is no object in the robot's path when it's moving to its next given coordinates. The sensor has the ability to detect an object within 21ft ahead of it. For our purposes, however, the sensor only needs to be able to detect within a foot in front of it. This device will be controlled by the Arduino Mega 2560 microcontroller. By insuring that the robot has object avoidance this now keeps the robot safe and in one piece when being used on the green.

The HMC6352 utilizes 2-axis magneto-resistive sensors. The compass uses a two-wire I^2C system to communicate to the robot and back to the computer. The common issue with using such compasses is the inaccuracy read when the compass operates near electromagnetic fields such as the metal frame of the robot and the motors that help move the robot. Because of this, the compass was designed to be placed on the robot opposite of the motors.

CMUcam3

The CMUcam3 has the ability to track a color (input as RGB values or YCrCb values) and return the x and y coordinates of the center of the mass of the given color and a value relating to how confident it is that it sees the given color. The camera is attached to a pan/tilt mechanism, which allows the camera to track in two dimensions.

The CMUcam3 and the pan/tilt mechanism will be placed on top of the robot and will be used to track the flagpole, which will be placed in the hole on the putting green. The combination of the compass (which is also attached to the chassis) and the panning of the camera will give us the direction the robot is facing and the angular position with respect to the flag pole.

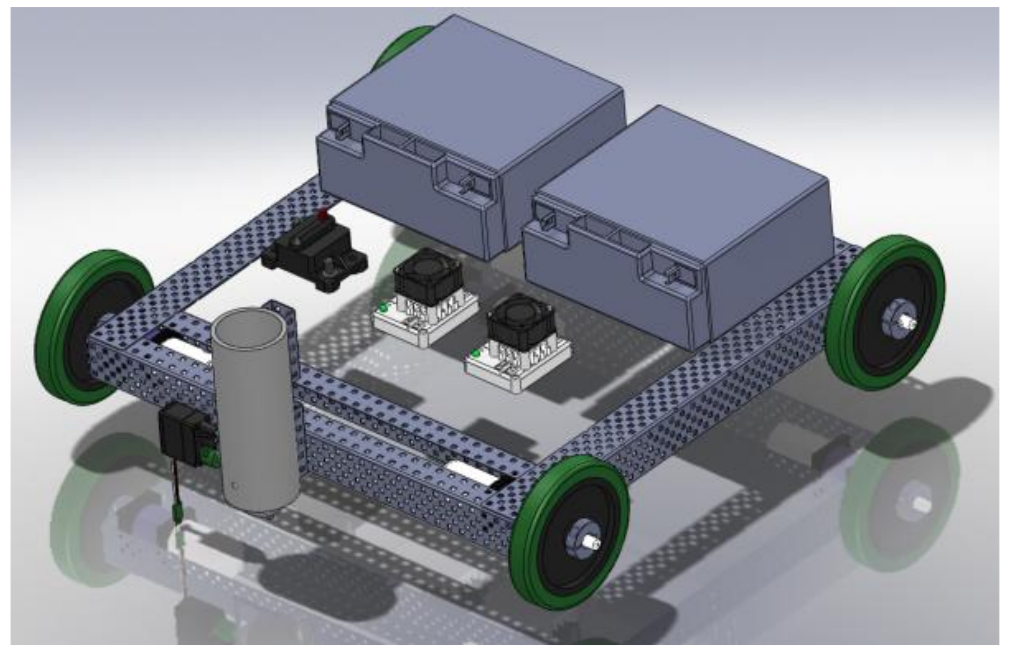


Software

The main problem that needs to be solved by the software is coordinating all sensor readings, actuating the servos/motors and communicating with the host. The chosen architecture is the Arduino development kit, which uses an Arduino Mega2560 as its microcontroller. This is an 8-bit microcontroller and though it has plenty of timers and multiplexed resources, the task given to the controller pushes its limits. To solve timing conflicts of the sensors, two interrupts are used. The most time critical of which has a routine that reads the instantaneous velocity of the motorized wheels, to perform as an odometer for robot navigation, and to keep it driving straight and at a constant velocity. By keeping this process interrupt driven, other important tasks such as motor control and communications can run without hindering sensor readings.

The robot has two modes of operation: manual and automatic. The first version of the robot software that was written to test its subsystems was only manually controlled through the host computer and its GUI. Simple directional commands are given to the robot (forward, backward, left, right, stop, and drop ball), by the host PC. These commands are read, and the proper action is taken, and while it performs the command given, all sensor readings are communicated back to the client. Should any navigational system fail, this mode can be used to guide the robot back to stable operation.

When all subsystems to the robot are functional, or a command given by the host PC is given to do so, the automatic mode is used. Here the robot will perform a self check, and wait for both a new coordinate and for a ball to be placed in its hopper. It then uses the camera system and compass to drive to the correct heading, face the target location of the ball and attempt to drive straight using the encoders, compass and camera system to keep it straight. Once at the location, the robot's frame for the ball dropper is used to determine where to drop the ball. At this point the robot drops the ball, drives out of the way for the player, and faces the flag to be ready to repeat the sequence for the next player.



Team Information

Top Row: Kari Thirumavalavan, Tenzin Seldon, Jeff Cosimano, Marcus Grant
Bottom Row: Jason Thrush, Cory Gregory, Derek Hugo
Too Busy With FIRST Robotics: John Gutmann

Name	Discipline	Role
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Marcus Grant	EE	Electrical Specialist
Cory Gregory	EE	Project Manager
John Gutmann	CE	Lead Engineer
Derek Hugo	CE	Secretary/AR Golf Representative
Tenzin Seldon	ME	Mechanical Specialist
Karikalan Thirumavalavan	EE	Customer Needs Representative
Jason Thrush	EE/CE	Research Specialist/EDGE Specialist

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