

The Caddiellac

"In the pursuit of perfection on the course, your clubs should follow your lead"

EE41430

High Level Design

Ryan Bernhold

Matt DePorre

Rachel Drumm

Colleen Tigani

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1. Introduction

This high level design outlines the basic design plans for The Caddiellac, a motorized cart that follows behind a golfer and carries their clubs. This report details the plans for Team Caddiellac's final Senior Design project, which is a cumulation of the Electrical Engineering undergraduate experience and allows the team to utilize the knowledge and skills acquired the past four years at the University of Notre Dame. The group consists of Ryan Bernhold, Matthew Deporre, Rachel Drumm, and Colleen Tigani.

This report outlines the problem statement and proposed solution, system requirements, a system block diagram, high level design decisions, and a discussion of some open-ended questions that will be explored further during the Spring semester. An outline of necessary components and anticipated costs is also included.

2. Problem Statement and Proposed Solution

When golfing, there are two major issues that one has to deal with. The golfer has to have access to a large selection of heavy golf clubs at any given time on the course. Additionally, golf courses are expansive and transporting these clubs is tiresome. Currently, there are three ways that this problem can be resolved: the clubs can either be carried around by hand, the golfer can rent a golf cart or a pull cart, or hire a caddie for the day. To carry the clubs by hand is cumbersome and tiring for the golfer. The latter two options become expensive for regular golfers. There is a need for a method of transporting clubs which relieves the golfer from carrying them from stroke to stroke, and also eliminates the necessity of renting an expensive piece of equipment or hiring someone to walk with you.

A proposed solution is to build a motorized cart that follows behind the golfer based on position tracking. The cart will resemble a typical pull cart, and will drive behind the golfer along the course. The cart will have a visual detection system which follows the golfer by identifying an LED pattern worn on his back. It will also use sonar detection to determine if there are any hazards in the immediate area or if it is driving too close to the golfer. The cart will have an accompanying mobile application that will communicate via bluetooth. This will allow the user to turn the follow capability on and off, as well as manually override the movement of the cart. This allows the golfer to take a swing, or use the restroom without his golf bag getting in the way. Additionally, if the cart gets in a tight spot, the user can control it back

on track. The robotic cart will be able to accommodate and transport the golfers personal golf bag in a secure manner.

3. System Requirements

The system requirements for this project can be broken down according to the features The Caddiellac is expected to demonstrate. The Caddiellac must be self-driving, incorporate golfer detection and following, allow for manual override, and have a user friendly design. If all requirements are successfully met, The Caddiellac will solve the problem of transporting golf clubs along the course in a reasonable, simple, and inexpensive manner. All numbers used in the system requirements were taken from the calculations of the sub-system demo.

First and foremost, The Caddiellac must have the ability to be self-driving. This includes the capability to carry the weight of a bag of golf clubs and maneuver along the golf course. The caddie must be able to maneuver along the terrain of the golf course, including up and down inclines, without tipping. The design must feature a low center of gravity to avoid tipping, along with the appropriate torque being provided by the motors to drive up inclines. The coefficient of friction on the wheels must also be great enough to resist slipping on surfaces. The Caddiellac must also have enough power to maintain itself through a full 18 hole game of golf.

The caddie will drive at the average pace of a golfer, 3 mph. It will be expected to drive up inclines of up to 15 degrees. This will require a torque of 2.399 Nm per wheel. In order to ensure that the Caddiellac does not slip on inclines, the coefficient of friction of the wheels must be great enough to overcome sliding. The caddie will be expected to last the entire duration of a golf game, 5 miles, which will require a battery of 6.5 Amp-hours.

The Caddiellac must also have the ability to follow the user. The caddie must be capable of detecting the position of the user, and then adjusting its path accordingly in order to follow the user along the course. Additionally, the caddie should have the ability to detect obstacles in the vicinity, including nearby trees, rocks, or golfers, and avoid collision with these obstacles.

The system must have the ability for a manual override. This will require a user interface in which the golfer has the ability to turn the following feature of the caddie on and off to stop the caddie when desired. It will also require the ability to

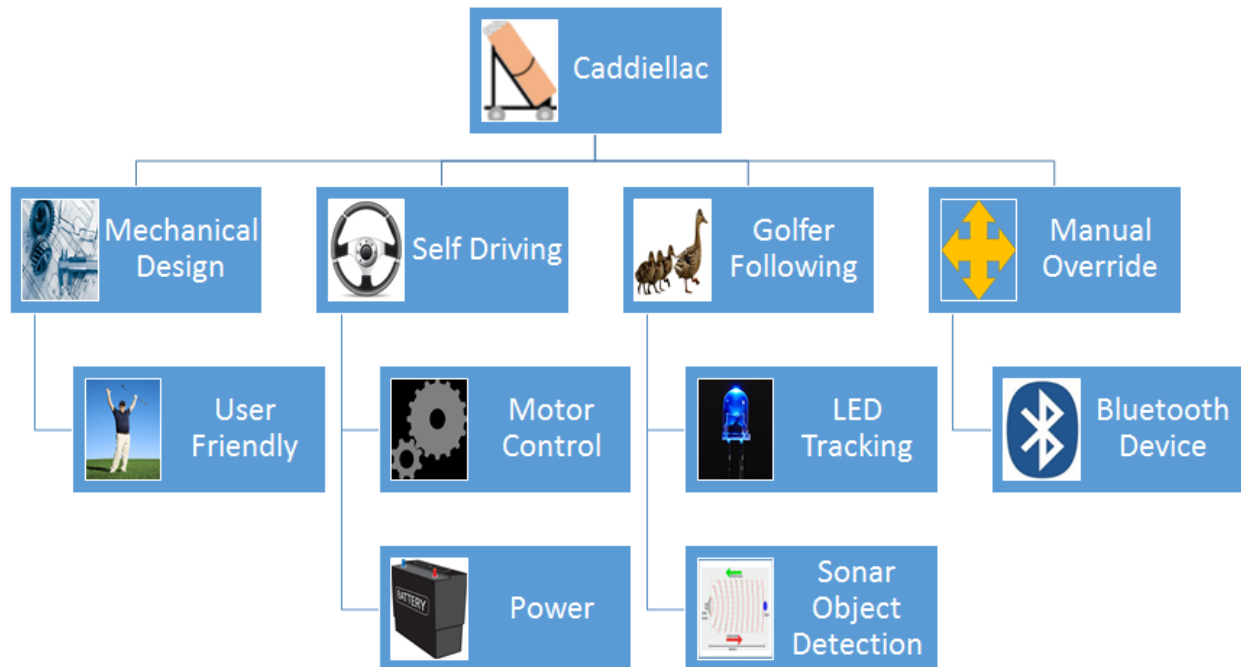
drive the cart forwards and backwards, as well as turning the cart left and right, in order to avoid any situations in which the cart may have gotten itself stuck.

The Caddiellac must have a user friendly design to facilitate ease of use for the golfer. The physical design must be sleek and clean, and hold the golf bag at an angle that allows for easy access of the clubs. The caddie must also be easily transported when desired, which imposes requirements on its height and weight.

In order to maintain transportability, The Caddiellac should be easily stored into the trunk of a car, which provides size limitations of 36" x 34" x 23". The weight of the caddie should allow for small amounts of lifting for the sake of storage. When the golf bag has been removed from the caddie, the maximum weight of the caddie will be restricted to 45 lbs.

4. System Block Diagram

4.1 Overall System



The overall system of The Caddiellac can be broken up into four main subsystems: mechanical design, self driving system, golfer following capability, and manual override feature. The mechanical design incorporates the user friendly interaction and aesthetics of the product itself. The self driving system can be divided into two main components, a motor control system that will accelerate and control the motion of the caddy, and the power device that will supply enough current to keep The Caddiellac functioning for a full game of golf. The golfer following will be accomplished with an LED tracking program in which a sensor will detect the LED pattern on the golfer and alter its speed and direction based on the location of the golfer. The sonar object detection will sense if there is any object in the immediate path of The Caddiellac to determine if it can advance. Finally, the manual override control allows the golfer to control the cart through a bluetooth device, which will be implemented through the golfer's cell phone.

4.2 Subsystem and Interface Requirements

The following section details the requirements of each subsystem:

Mechanical Design

User Friendly: The Caddiellac is designed with the user as the main focus. It's goal is to assist the golfer so he or she can better enjoy the experience on the course. Therefore, the user friendly design is a key component of the mechanical design subsystem. Not only will The Caddiellac be functional it will also incorporate details for the user. The main frame of the product will position the clubs for easy access to the golfer while maintaining a stable configuration to handle the course. Additional features such as cup holders, a cigar clip, and pockets for various items will contribute to the overall appeal of The Caddiellac design.

Self Driving

Motor Control: The Caddiellac will have the ability to maintain a constant speed around the course. This requires a motor controller to control the amps provided to the motor assembly. Going uphill will require significantly more amperage than traveling on a flat or downhill terrain to get the extra torque and maintain speed. The motor controller must be able to handle the peak current required by the motor.

Power: In order to power The Caddiellac, a battery rated at 12 Volts, and at least 19.1232 Amp-Hours is needed. This was calculated in the spreadsheet by first determining the torque per wheel need to be exerted (or the torque needed to be output by each motor on the drive wheels), accomplished by finding the desired speed of the cart, the force per wheel, the uphill power draw, and the wheel radius. The torque per wheel was used in the Speed Calculations to make sure the output torque of the motors would give the desired speed of The Caddiellac. To determine the number of amp-hours required for a round of eighteen holes of golf (approximately three hours of driving time), the current drawn from the motor at various terrain levels was averaged. We assumed The Caddiellac will be travelling flat terrain 60% of the time, uphill 20% of the time, and downhill 20% of the time. The average current draw for the motor over three hours of drive time was found to be 3.1872 A. This current multiplied by three hours of usage gave 9.56 Amp-Hours per motor, or a total of 19.1232 Amp-Hours. The battery chosen for The Caddiellac is a 12 V, 22 AH battery.

Golfer Following

LED Tracking: The Caddiellac will have the capability to follow the user along the golf course through a visual detection system that utilizes an LED pattern that will be worn on the back of the golfer. The LED pattern worn by the golfer will be lightweight, comfortable, and unburdensome to the golfer. It will have a unique pattern of LED's which will be able to be recognized by the camera installed on the caddie. This camera will continually grab snapshots of the video input, and scan the image in order to detect the location of the LED's within the frame. By using calibration information from the camera, the system will be able to calculate the location of the golfer in relation to the caddie. This will allow The Caddiellac to adjust the direction of its course to follow in the direction the golfer is walking.

Sonar Object Detection: The Caddiellac will have a built-in sonar object detection feature in addition to the LED tracking system. The purpose of this detection system is to recognize objects in the immediate area that could be a hazard to the caddie. Such objects include nearby trees, rocks, or other golfers that may appear in the path of The Caddiellac. The sonar sensing will detect hazards such as these that are within the immediate path of The Caddiellac. It will then notify The Caddiellac so that it can change its course slightly to avoid the object, wait for the obstacle to pass out of its path, or pause for a manual override from the user in particularly difficult situations.

Manual Override

Bluetooth Device: An additional feature The Caddiellac will have is a manual override. This feature will be used for when The Caddiellac follows the golfer into tight spots, the golfer wants to suspend follow mode, or when the user wants to control it for other reasons (e.g. get out of the way of a shot). The Caddiellac will be bluetooth enabled and an app will be available for download with a simple user interface to control and suspend the Caddiellac's movements.

4.3 Future Enhancement Requirements

There are several additional features for The Caddiellac that could potentially be incorporated into future design to enhance its performance. One possible option is a more advanced detection system. Such a system would be more robust, have the ability to identify a greater number of obstacles and have greater knowledge of how to avoid them. It would also have improved golfer identification, in order to decrease the likelihood of losing the golfer on the course.

Another potential enhancement would be incorporating variable speed into the device. The current design restraints on The Caddiellac allow for a singular, pre-programmed speed. An enhanced design would be able to adjust the speed at which The Caddiellac drives in order to match the individual pace of the golfer who is being followed.

One other future design requirement would be a mechanical design improvement. Future versions of The Caddiellac should seek to provide a more sleek, lightweight, and compact design. An ideal design would have the ability to be easily folded for storage, and would be as lightweight as possible to accommodate transportation.

5. High Level Design Decisions

Each subsystem can be analyzed by examining the high level design decisions that correspond to the requirements. For the self driving subsystem, the motor control aspect will have two motors for several reasons. Primarily, each motor will control a set of wheels, which allows better directional control. Plus, having multiple motors contributes to the torque which allows for a greater flexibility in terms of terrain The Caddiellac can handle. Another decision within the self driving subsystem includes the battery component. The decision to have a high quality battery that will be a large portion of our budget is to ensure that The Caddiellac will function for the lifetime of a full golf game. This decision also ties back into the mechanical design subsystem since it makes The Caddiellac more user friendly if the golfer does not have to charge the device as he or she plays.

Within the golfer following subsystem, the LED tracking technology was chosen for efficiency and accuracy purposes. By having The Caddiellac determine the position of the golfer based on the pattern of LEDs, the calculation has better accuracy incorporating the angle and distance of the golfer. Another decision included the sonar object detection that will prevent The Caddiellac from moving if anything is an obstacle in its path. This also contributes back to the user friendly design since the golfer does not need to be worried or concerned with interference in the space between himself and the device, such as an animal or another golfer that crosses the path unexpectedly.

Lastly, within the manual override subsystem, the bluetooth device control will be implemented as a failsafe option to control The Caddiellac. This will allow the golfer to control its direction if the following technology is not ideal, such as in a

parking lot or crowded area. This also corresponds to the user friendly aspect of The Caddiellac. The choice for bluetooth comes from the capability to implement this technology into any smart phone, which is a common device the golfer would own. Overall, the decisions incorporate a front to back design, which keeps the user in mind for all aspects of the device.

6. Open Questions

There are several open questions that must be answered through further research, testing, and analysis over the course of the Spring semester. These questions are related to the method through which several of the subsystems are executed. The subsystems methods that will be explored in greater detail are the method of golfer tracking being used, the hazard detection, and the format of the user interface system.

The method of golfer tracking that will be implemented is a visual tracking system that will detect an LED pattern worn by the golfer and adjust its path accordingly in order to follow the golfer along the course. This method of golfer tracking was selected for its relative ease of execution, efficiency, and accuracy. However, this method of visual tracking also presents several limitations to tracking ability. Primarily, visual detection will be limited to scenarios in which the LED pattern is directly visible by the camera on the caddie. This means that the golfer must always have his back facing the caddie and be relatively square. This limits the mobility of the golfer, and requires him to always be cognizant of turning too quickly for fear of the caddie losing its detection. Additionally, requiring the golfer to wear an LED pattern on their back presents a slight burden to the golfer, and may not be a desirable feature. It will therefore be necessary to continue to explore other forms of visual tracking that would allow the golfer more flexibility in movement.

The method of hazard detection should also be further examined during the Spring semester. The current solution is to implement a sonar sensing system that will identify nearby obstacles including trees, rocks, and other golfers. This method will ensure that the caddie does not collide with any large objects that could be easily avoidable, and will also instruct the caddie to stop if it is following behind the golfer too closely. The consequence of using such a system is that the caddie will not be able to determine what the obstacle is, only whether or not an obstacle is present. This could become an issue if the caddie detects small obstacles that should not actually be considered hazards, or if it is approached by another golfer which stops it on its course and prevents the caddie from continuing. Other possible solutions

include expanding the visual tracking system to identify specific hazards, or imposing limitations on what is detected. Another potential problem of sonar sensing is its inability to detect some obstacles such as sand traps that are level with the surface of the course. This could also be avoided by expanding the capabilities of the visual detection system.

One other subsystem that will require further exploration is the format of the user interface system. The current system involves developing an Android application which will communicate with The Caddiellac via Bluetooth. This is the best option in terms of cost, execution, and accuracy. However, it also limits the utility of the caddie to Android users. Other possibilities include expanding the application so that it can be used on an iPhone as well, or designing a remote control that the user will carry with them on the course. The inclusion of a remote will eliminate smartphone limitations for manual override, however it would also increase the cost of execution through the addition of hardware components.

7. Major Component Costs

The major component costs of The Caddiellac are within the self-driving subsystem, which are outlined in the specific parts in the table below. The other necessary components needed for the overall system are the estimated values below.

Qty	Part Number	Part Name	Manufacturer / Distributer	Price (\$)	Total Price (\$)
1	MH20567	UB12220 Universal Battery	Amazon	44.95	44.95
2	M5-RS555-12	RS555 Motor - 12V	BaneBots	6.25	12.5
2	P60K-55-0004	P60 Gearbox: Stock, Standard Shaft, RS-540/550 Mount, 104:1	BaneBots	54.5	109
1	A00067-00048	Battery Charger	Sears	24.9	24.9
1	RB-Dim-23	Sabertooth Dual 25A 6V-24V Regenerative Motor Driver	RobotShop	124.99	124.99
1		Board		50	50
1		Bluetooth Module		15	15
1		Sensor		8	8
1		Camera		25	25
1		Accelerometer		15	15
		Construction Materials		60	60
				Total:	489.34

As it can be seen, the project is close to the upper budget limit of \$500. This will be an area of focus moving forward, as the group will have to work to eliminate unnecessary costs to remain within the budget restrictions.

8. Conclusions

The high level design outlined in this report provides an overview for the development of The Caddiellac. This project will serve as the culmination of our Senior Design project through final development, construction, and testing of its design throughout the Spring Semester. The final result of this project will be a motorized cart that follows behind a golfer based on position tracking, providing the golfer with a hands-free, easy way to transport their heavy clubs along the course. Based on our design plan, we believe The Caddiellac will be a successful project, provided we complete each system requirement.