Formal Proposal 1

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Proposing ‘Gator Raider’

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Abstract

Gator Raider is an autonomous tank that is meant to demonstrate the potential of coil gun technology as a modern weapon system and satisfy the requirements of Intelligent Machine Design Lab. It utilizes a single coil gun mounted on top of the robot designed to puncture party balloons. It will navigate itself, avoiding obstacles and searching out targets to recognize and destroy. It uses Ackerman steering like a car to provide smooth, gradual turns and ease the process of aligning with a target. This eliminates the need for calibrating two differential motors together and eliminates jerky turning maneuvers.

Gator Raider demonstrates the basic components of necessary technology for a robot that can enter dangerous areas and eliminate threats without human intervention. Gator Raider can guide itself through and environment, detect targets, aim itself, and eliminate the targets by itself. This is a very beneficial resource to have in any police or military force, especially in today’s widespread terrorist threat environment in areas where radio contact with a robot or drone may not be possible.

Introduction

The real life application that Gator Raider strives to fulfill is an autonomous weapon that can be deployed and destroy targets without human aid. There are many instances where this is beneficial, especially in the Middle East where mud and concrete buildings can restrict radio signals or anywhere that radio silence needs to be maintained. An autonomous robot cannot be taken over by enemies by overpowering or jamming the signals, nor does it require constant monitoring of a human operator. This saves on necessary manpower and opens up the possibility of fleets of robots working together.

The objective of this project is to build a robot that can navigate a curved path of cardboard walls while scanning these walls for balloons taped to them. Once a balloon has been located, Gator Raider will align itself with the balloon, adjust the elevation of its gun, and pop the balloon with a dart. It will then continue on its original path looking for more balloons. In order to complete this entire mission successfully, Gator Raider will need to be able to make steering calculations and adjustments based upon how far away the target it from the aiming axis of the cannon and the robot in general. This may involve making backup maneuvers. The robot will also need to be able to reload itself after each shot.

Integrated System

1. **Chassis**

Gator Raider uses a multi-level chassis system to provide maximum mounting surface area. The chassis will have two layers, the upper level holding the coil gun and its elevation control system. This upper level is 10” x 5.5” providing plenty of space for the coil gun and its capacitor bank. Mounted to the underside of this upper level and sticking out of the front of the robot is the webcam that is used for target detection. There is a 2.75” gap between the upper platform and the lower platform.

The lower level of the chassis is 18” x 10” and will hold the main electronics, battery, and ultrasonic sensors. It will also serve as the body of the chassis, meaning the motor, wheels, and steering system will be mounted to this. The ultrasonic sensors will be mounted on the front of this platform with the battery directly behind for easy access. Underneath the upper platform the Raspberry Pi and Arduino Uno will be mounted, allowing easy access but also affording protection from damage. On the rear of this platform the LED array that indicates the robot’s current process will be mounted for easy viewing.

1. **Coil Gun**

As previously mentioned, the coil gun will be mounted on the upper chassis platform. It will be made out of a thin plastic tube approximately 10” long. One end will be attached to an ordinary cabinet hinge which will be mounted on the robot. This hinge will allow for elevation changes on the coil gun. The coil will be wrapped about halfway down the barrel tube. It will be made out of 12 AWG copper wire and take up about 2” of tube area. At the hinge end of the coil gun, a projectile magazine in the form of a rectangular hopper will feed projectile into the tube through a slot cut in the top of it. A solenoid will push the projectiles one-by-one into the tube as the gun fires, giving them an initial velocity and overcoming the static friction.

The firing current for the cannon will be provided by capacitors, currently a single 3450 µf 75v capacitor. This may be increased or decreased after firing tests are performed. The capacitor(s) will be mounted on the upper platform, the first one behind the coil gun and subsequent ones beside it.

Elevation of the cannon is controlled by a threaded rod which runs through the upper platform and is turned by a small stepper motor. The elevation is measured by a spring that acts as a variable resistor and slide up and down along with the coil gun. The elevation control system is attached to the barrel in front of the hinge and behind the coil.

1. **Ackerman Steering System**

Gator Raider utilizes an Ackerman steering system for the front wheels which will be actuated by a servo. The main axle support bar will be made out of Balsa wood like the chassis and will actually be part of the chassis. The two steering arms will be 3D printed with ABS plastic and have 5/16” steel rods inserted into them to act as axles. The Ackerman control arms that reach from the servo to the steering arms will be made out of sheet steel cut from window flashing. The robot will have four rubber wheels with 5/16” nylon sleeve bearings that will slide onto the axles.

1. **Rear Drive System**

The rear wheels are driven by a single motor turning a differential which turns the same type of wheels as the front wheels. The axles are also 5/16” and fit into nylon sleeve bearings. Because of the size of the motor mounting bracket, the front of the robot is slightly lower than the rear.

1. **Control/Processing**

I have chosen to use and Raspberry Pi as my processor board and an Arduino Uno as my microcontroller. I chose the Pi because of its reputation and ease of programming. I chose the Arduino because I already had one available, though I would have chosen it anyway because of its reputation.

Actuation

1. **Main Drive**

Gator Raider is driven by a single motor. The motor I have selected for my robot is a 12V DC gearbox motor. It has a max RPM of 100 and generates over 400 oz. /in. of torque. It is manufactured by ZHENG Electronics and I purchased it from Amazon. I chose this motor because of its high torque and fast speed. Since it operates off of 12 volts, it will work perfectly with my 11.1 volt battery.

My motor has a 6mm output shaft which will turn a differential for an R/C car. This differential will turn two 5/16” axles which will turn the wheels. My original goal was to 3D print a differential, but the amount of time my other classes take up and the size that the differential would have to be for the printer to print the gears within a reasonable tolerance has led to that idea being scrapped, at least for the time being. However, I did learn a lot more about Solidworks through the design process.

1. **Steering System**

The Ackerman connector rods will be turned by a servo. I am using a FP-S28 servo manufactured by Futaba. It is an older servo that has since been discontinued, but it was designed for steering remote control cars so it has the necessary torque and attachment arms for my purpose. The main reason I selected this servo was because my dad already owned several for his R/C cars and therefore saved me money.

1. **Coil Gun Elevator Rod**

Since the coil gun has very little weight, the motor to adjust its elevation angle does not need to be very powerful. I am using a very small stepper motor so that I can control the elevation as precisely and accurately as possible.

1. **Reloading Solenoid**

The reloading mechanism is a very simple contraption that simply involves pushing a dart into a tube quickly as the cannon fires. Loading the projectile into the loading ramp portion of the gun barrel will be done by gravity so it is only necessary to have a small solenoid behind the gun barrel that pushes each projectile along the barrel axis. This solenoid can be quickly manufactured by me as it does not have to be super complicated. It is important to note that this solenoid will fire a split second before the coil fires so that the projectile has an initial velocity and has already overcome static friction.

Sensors

1. **Ultrasonic**

Objects will be sensed by three ultrasonic sensors. They are mounted on the front of the lower platform on the main chassis. One is pointed straight forward and the other two form a 90 degree angle to each other and a 45 degree angle to the center one. They are slightly angled upwards so that when the robot is set on the ground, they will fire level with the ground since Gator Raider leans slightly forward. They are also set close together and fan out so to minimize blind spots on the front of the robot. They each fire one right after another, each one waiting for the echo from the previous one before firing so as not to listen to each other’s echoes and give false readings. I purchased a three-pack of sensors from Amazon that was manufactured by Mihappy. I selected these sensors because they had excellent customer reviews, were reasonably priced, and Prime eligible.

1. **Target Detection Camera**

Target detection is sensed by a webcam which acts as my special sensor. It is mounted under the front of the upper chassis platform. The webcam connects straight to my Raspberry Pi via a USB cable. I do not know the manufacturer of my webcam, it is one that I have had for a couple of years.

1. **Coil Gun Elevation Sensor**

The elevation of the coil gun will be calculated by a spring resistor that is fixed to the barrel of the coil gun with a small hinge (so that it can remain vertical as the elevation changes) and allowed to freely slide through the upper chassis platform and across an electrical contact. As the gun barrel is lowered, the amount of spring between the contact and the ground will decrease, therefore decreasing the resistance in the circuit. The computer will measure this resistance and it will be calibrated to determine the elevation angle of the coil gun. I got this idea from looking at how the ‘throttle’ of my old slot car set worked.

Behavior

1. **Obstacle Avoidance**

As previously mentioned, the three ultrasonic sensors are set close to each other and angled out to eliminate blind spots in front of the robot. That said, the main mission of Gator Raider is not to navigate around small objects, but to guide itself through a course of cardboard walls. It will use fuzzy logic to smooth out its path and to utilize its Ackerman steering to its full potential.

1. **Target Detection**

Gator Raider will use its webcam to detect balloons taped to the walls of its course. As soon as it sees a balloon, it will stop and calculate the horizontal distance from the balloon to an axis drawn through the center of the robot from the rear to the front. Using the ultrasonic sensors, it will determine the distance to the wall that the balloon is taped to. Then Gator Raider will make a steering adjustment based on the above information and move slowly forward until the balloon is centered. The optimal firing distance will be two to six feet away so if the robot is closer to the balloon than two feet when it detects the target or the target is further off center than it can turn while keeping the target in optimal range than it will perform a rapid multi-point turn maneuver to close the distance. The maneuvers will be small and fast because Gator Raider does not have any sensors on its back or sides so it cannot safely back up far without possibly colliding with something.

1. **Coil Gun Elevation**

After the target has been aligned horizontally, Gator Raider will aim the coil gun vertically. Using distance to target information from the ultrasonic sensors, height information from the camera, and firing velocity information from test firing the computer will calculate the gun angle using projectile motion formulas. Then the stepper motor will turn until the elevation sensor reads the correct resistance.

1. **Firing**

Once the coil gun is fully aimed, the robot will initiate charging the capacitor bank. Once it is fully charged, a firing LED will blink for several seconds allowing a human to intervene and stop the firing sequence as a safety precaution should a malfunction occur and Gator Raider target a false target. Then the projectile injector solenoid will fire, pushing a dart into the barrel and giving in an initial velocity. Almost consecutively, the capacitor bank will discharge into the coil accelerating the projectile to its necessary velocity. After the gun has fired, Gator Raider will revert back to its previous programming and search for more targets. I am intending on making the robot stop searching for a balloon color after it has fired once at it so that it does not get hung up on a difficult target or continuously fire at the balloon scraps.

1. **Complete Order of Behaviors**

* Begin navigating closed course, avoiding walls and searching for colored balloons
* Identify a balloon on the wall
* Make adjustments on steering to align with the balloon and drive the short distance to turn making small backup maneuvers if necessary
* Calculate target range and height
* Determine necessary gun angle to hit target and make necessary elevation adjustments
* Charge gun
* Give firing sequence warning as emergency precaution
* Fire coil gun
* Repeat

Conclusion

Most of the materials needed to manufacture have already been purchased and are ready for assembly. There are a couple of things such as wire and the stepper motor for the elevation control that still need to be purchased, but progress is nominal. Assembly is scheduled to start next week and I hope to have the chassis with all sensors and processors/controllers mounted by the end of next week. A Solidworks model has been created as a guideline although some things will be different. Making the model has also showed me changes that would be helpful, mainly dimensional changes.