IR Tracking NERF Sentry Gun

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1 Introduction

1.1 Objective

Sentry guns are becoming more of a novel idea since they give the ability to put up a defense against enemies without needing somebody to be with the weapon itself. Since sentry guns use sensors to track targets and can engage targets without human intervention, they can be put in dangerous war areas without risking the safety of a human operator. Currently, one of the most prominent sentry guns in use is the SGR-1 which is used on the border of South Korea. It has "heat and motion detectors to identify potential targets more than 2 miles away" [1]. This kind of tracking is also being used in the development of robot soldiers. This field is rapidly emerging that it has been predicted that "the US military will have more robot soldiers on the battlefield than real ones by 2025" [2]. However, there are still many problems that come along with sentry guns. As these guns are often placed at borders, it is not safe for a person to go out into the war zone and move the gun. The technology needed to implement these guns also limits the mobility of the gun as it makes them extremely heavy. Regarding the decisions that tracking systems must make, autonomous weapons expert Paul Scharre explains that in war zones, "the level of ambiguity, and [the] context required to makes these decisions, was such that it's very difficult to imagine programming a machine to make decisions [about using lethal force]" [3]. Overall, the lack of portability and unreliable tracking systems associated with sentry guns severely limits their usefulness.

Our goal is to build a modified NERF sentry gun that implements a tracking system that can identify and engage targets. This tracking system will be implemented with an IR system that relays information about possible targets to a microcontroller. The microcontroller will be programmed to take positional data from the sensor and determine where the gun needs to be moved to and whether the target is able to be engaged. To differentiate from other implementations, we will not rely on a separate computer to drive the targeting system. Since a computer will not be needed for operation, our project will be more readily deployable compared to other implementations. Our system overall should be adaptable overall to varying scenarios.

1.2 Background

Similar projects have been done involving modified NERF guns, but most others implement their tracking system with webcams and OpenCV [4]. As these options require a computer to be hooked up to the gun, it limits the portability of the gun. Instead, we will be using an infrared camera from a Wii Remote, we should have lighter hardware requirements for tracking which will lead to a faster setup time [5].

The main characteristic that will differentiate our implementation from other implementations would be portability. We will need to create a quick and responsive system that can acquire and engage targets from at least 10 feet away. Instead of using OpenCV, we plan to implement our tracking system by having the infrared camera pick up IR signatures from an IR led that targets will be wearing. The IR tracking system will then send this information to the microcontroller. The microcontroller will communicate to the target system's actuators to move to the correct location so that gun will be aimed at the target. Finally, the microcontroller will tell the firing system to fire.

1.3 High-Level Requirements

- Tracking system must be able to identify and give positions of targets that are within 10 feet of the gun.
- Weapons platform must be able to use this information and independently engage a single target at a time once it is within 10 feet of the gun.
- Entire system must be as portable as possible and ideally able to be deployed at a moment's notice.

2 Design

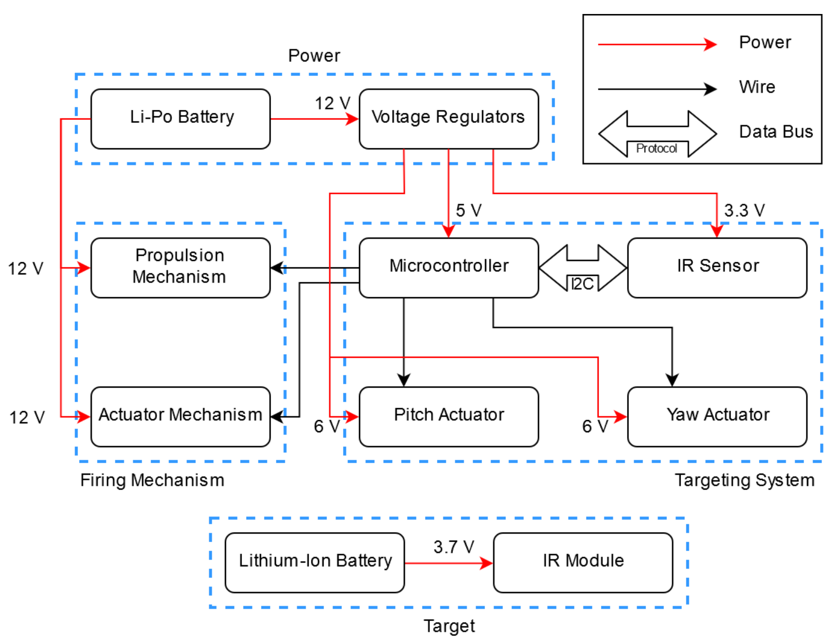

Figure 1: Block Diagram

The sentry gun's design can be broken up into three subsystem blocks - a power system, a targeting system, and a firing system. First, the power system supplies the entire system from a battery, meeting the varied needs of each subsystem through regulators if needed. Next, the targeting system has three elements - an IR camera sensor for active target detection of the IR target, an actuation mechanism that moves the sentry into firing position, and a microcontroller that orchestrates information and commands between the sensor, actuators, and firing system. Finally, the firing system would consist of an actuation mechanism that moves darts into a propulsion mechanism. Overall, the system is meant to be built for portability and deployment on demand. A fourth block external to the system, the target, provides the system the identifying IR signal to target and shoot at.

2.1 Power System

The entire system will draw power from this block. However, since other blocks have varying needs, the power system needs to be able to provide for their demands.

2.1.1 Battery

The largest current is most likely found in the firing system's motors. So, the battery should be rated to handle the current demands of that system and be able to keep the system powered otherwise. Initial research into prospective 3S motors places the stall current at about 8 amps per motor. Using three of these motors would mean the battery should allow for a maximum discharge of 24 amps. Further research into the idle current places continuous current draw to at least 0.3 amps per motor, meaning about 0.9 amps are drawn continuously if the motors were continuously running.

Requirement 1: The battery must be able to keep the system completely operational for at least 1 hour, implying the battery should have a minimum capacity of 1,000 mAh.
Requirement 2: Current draw at max would be around 24 amps, so assuming a minimum 1,000 mAh capacity, the battery should have a C rating of at least 25.

2.1.2 Voltage regulators

The targeting system is likely to have components that will need regulated voltage. As the voltage from the battery decays, these regulators should still be able to provide their specified voltages within tolerance.

Requirement 1: The voltage regulators must be able to keep any components that require any regulated voltage operational over its operating hour. Likely, 3.3V, 5V, and 6V of regulated voltage will be required.
Requirement 2: The voltage regulators must be able to maintain their specified voltages within +/- 5% over its operating hour.

2.2 Targeting System

The targeting system collects information from the environment. If a target is found by its sensor, it sends information to its microcontroller, which decides how to order the actuators to move such that it aims the sentry gun into a firing position. If it is in a firing position, it should then communicate to the firing system to fire.

2.2.1 IR sensor

This IR sensor will need to be able to discern a target from the environment. It will do this by detecting some external IR source that is easily identifiable relative to the surrounding environment. It also must be able to acquire a target from an acceptable distance away.

Requirement: The IR sensor must be able to acquire a target from at least 10 feet away.

2.2.2 Microcontroller

The microcontroller should be able to communicate with the system's sensor to gather information and use this information to tell the targeting system's actuators to move appropriately. Once it determines it is in position, it should then tell the firing system to fire. It should be low latency to respond quickly to any targets in sight.

Requirement 1: The microcontroller should be able to communicate over I2C to the system's sensor.
Requirement 2: The microcontroller should be able to provide appropriate pulse widths to the targeting system's actuators.
Requirement 3: The microcontroller should be able to communicate to the firing system to fire by first telling it to prime its propulsion mechanism and then tell its actuation system to begin loading darts into the propulsion mechanism.

2.2.3 Actuators

The actuation system should have two rotational degrees of freedom, pitch and yaw. It should be able to take information from the control system and move the system towards a firing position.

Requirement 1: The yaw actuator should be able to yaw over a 360° range of motion.
Requirement 2: The pitch actuator should be able to pitch over at least a 90° range of motion, or at least ±45° with respect to the ground.

2.3 Target

The target is an external device worn by a target that will be sensed by our targeting system. Since this will be worn, this should be as compact as possible while still being able to be sensed some distance away.

2.3.1 IR module

The IR module should be able to generate a strong IR emission. This emission should not only be strong enough for the targeting system to detect, but also it should be detectable from at least 10 feet away.

Requirement 1: The signature generated should be strong enough to be acquirable from the targeting system from at least 10 feet away.
Requirement 2: The module should be as compact as possible, at most a 2" by 2" footprint.

2.3.2 Target battery

The target will draw power from this battery. It will need to be able to keep the IR module emitting continuously over the operating time of the sentry gun.

Requirement 1: The battery should keep the IR module operational for at least 1 hour.
Requirement 2: The battery should be as compact as possible, at most a 2" by 2" footprint.

2.4 Firing System

Once the targeting system determines that the sentry is in a firing position, the targeting system would order the firing system to fire by first letting the propulsion system prime for firing, and then letting the actuation mechanism begin moving darts into the propulsion system, beginning the onslaught.

2.4.1 Dart propulsion mechanism

Once the targeting system determines the sentry is in firing position, a signal would be sent to the propulsion mechanism to begin spinning up. When the dart actuation mechanism moves a dart into the propulsion mechanism, the propulsion mechanism would in turn propel the dart towards the target.

Requirement: The propulsion mechanism should be able to propel darts at least 10 feet.

2.4.2 Dart actuation mechanism

Once this mechanism receives a signal from the targeting system, it should begin moving darts into the dart propulsion mechanism, which should be primed for firing by this point.

Requirement: The dart pushing mechanism should provide a rate of fire of at least 3 darts per second.

2.5 Risk Analysis

Out of all the system blocks, the targeting system has been identified as the largest risk to project completion. Targeting has the most components to it, and it determines if and when the system should fire. Our sensor would need to be able to find a target in its environment and acquire positional information. The microcontroller should be able to take this information and determine how to command the actuators to move towards the target. The actuators would need to move fast enough to keep the target within line of sight. Finally, it sends out the signals necessary for the firing system to work. This component is mission critical since the entire project and its core mechanic, to fire at a target, depends on this system working.

Our choice of sensor should be limited to sensors that can discern a certain specific target from its environment. This means motion or range-based solutions should not be considered since these are too unreliable by being too sensitive. Additionally, the sensor should be quick and require the least amount of software and hardware. As such, computer vision should not be used since there is an amount of overhead associated with this system.

Our choice of actuator is narrowed to motors. DC motors would provide rotation based on its sheer speed, but they do not necessarily provide feedback nor precision. They could move the system quickly, but by themselves they cannot be finely controlled. Servo motors would provide finer control and moderate speed, but they can be limited to the torque they can provide. Finally, stepper motors would provide the finest control and great torque, but its form factor, hardware requirements, and speed can prove problematic, especially since the project is meant to be portable.

Our choice of microcontroller is going to depend on the interface our sensor communicates through as well as its processing speed.

3 Ethics and Safety

The nature of automated sentries presents a few ethical and safety concerns. The projectile has the potential to harm people and property, violating the IEEE Code of Ethics, #9 [6]. To minimize physical risks, we will use NERF darts which are lightweight, frequently used safely by children, and are therefore unlikely to do damage during normal operation. When building the sentry, we will be careful to never point it at any person or delicate object in case of an accidental firing. To prevent harm when the sentry is used inappropriately, we will adjust the speed at which the dart comes out so that its force at impact is further reduced.

Another concern is the fact that there will be moving parts which could pinch fingers or catch on objects. The area surrounding the physical aiming system should always be clear and before testing we will check to make sure the area is not blocked. The finished project would have a housing that will cover the motors allowing them to move while preventing outside objects from getting caught in the motors. In accordance with #1 of the IEEE Code of Ethics, we will disclose these possible dangers to the user [6].

We also want to make it clear to bystanders that this is a not a harmful firearm. Part 272 of Title 15 of the Code of Federal Regulations on foreign commerce and trade states, “toy, look-alike, and imitation firearms” must be marked with a “blaze orange” [7]. While this regulation does not require NERF guns to have orange tips on the muzzle, we will include this to make it more evident that it is a toy.

Because we will be using a LiPo battery, there are certain safety measures we must implement to prevent overheating, overcurrent, overcharging, and overdischarging. In order to prevent overheating, a thermistor will be used to regulate the battery and cut it off from the rest of the electronics if it becomes too hot. The battery will be select to ensure that it can provide adequate current without the risk of overcurrent. We plan on using a commercially available charger in order to eliminate the risk of overcharging as well as a monitor circuit will be used to ensure that its voltage does not drop below 3.0V/cell as suggested by “Safe Practice for Lead Acid and Lithium Batteries” on the ECE 445 site. [8] We also plan on following all best practices for storing and handling these batteries, which means, we will transport these batteries in an ammunition canister as recommended, and then they will be stored in these containers in the LiPo locker in the senior design lab when not in use, following laboratory safety protocol.

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