BRO-NS
Bluetooth Remote Operated Nerf Sentry

EEL 4914: Senior Design I
Divide and Conquer V2
University of Central Florida
Department of Electrical Engineering and Computer Science

Group 24

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Project Narrative

The primary motivation for this project was to create a remote controlled nerf turret and have fun shooting targets. We all grew up playing with nerf guns so we figured we could design and build one in the form of a sentry, whilst being controlled by Bluetooth software, which we make use of in our everyday life. This project would blend our skills with hardware and software within our majors, seamlessly. Turrets such as this sentry can be utilized by law enforcement and military units for professional, non-lethal simulation. This project is complex enough to challenge our skills in design and application whilst being cost effective in its requirements and in time. Our decision matrix shows the types of project designs we considered and how we came to this final decision.

The primary goal of this project is to design and build a functioning prototype of a Bluetooth controlled Nerf sentry turret that can fire at selected targets accurately and efficiently. It will be to connect to our smartphones, rotate in multiple directions, use a small amount of power while untethered, and reload magazines. We plan for this sentry to be lightweight and portable, allowing you to take it on the go and place it where you like to then control it with its Bluetooth connectivity. It's practicality and ease of use is that of high power in launching projectiles and only drawing a small amount of power. By it being remote controlled, the user will have the target making decision, thus limiting false target acquisition.

The Nerf sentry will be a system connected via Bluetooth to a smartphone that will make use of software and hardware enabling it to rotate in different directions on a dual axis chassis, load Nerf darts as ammunition from the magazine inserted and fire at the target selected by the user after rotating to point at it. Once the user has fired the desired amount of ammunition at the target, the user can rotate to select another target and continue firing. If the Nerf sentry is out of ammunition, the sentry can replenish the magazine inside.

This project will be complex but practical while being budget friendly. Our team was informed of this project's idea's popularity after we thought of it but we still wanted to take on the challenge in our own way. We were deciding between using airsoft, paintball or Nerf as the firing mechanism and ammunition type source. Airsoft and paintball would be more accurate than nerf but more costly, while the latter also being messy. Previous years' versions of this project included face recognition software and color detection software, connected via Bluetooth or wifi.

Design Specifications

- Wirelessly controllable
- Wireless range of ~ 10m
- 80% accuracy within 5m
- 50% accuracy within 10m
- Maximum projectile distance of at least 15m
- Will be able to fire projectiles at speeds ~ 15m/s
- Magazine capacity of 5+ projectiles
- Launcher magazine can be replenished in under 10 seconds
- Use less than 30W power
- Will be deployable in under 3 minutes
- Weigh less than 10lbs
- Can operate for at least 10 minutes on a single battery pack
- Must run completely untethered with no cables connected to outside devices for power or data transmission
- Can identify and fire on a target within 10 seconds of gaining vision on suspect
- The turret will have a horizontal range of motion of at least 135°
- The turret will have a vertical range of motion of at least 90°
- Turret will be able to complete a sweep on its horizontal aiming axis in 3 seconds
- Turret will be able to complete a sweep on its vertical aiming axis in 2 seconds

With these design specifications, our goal is to make the wireless sentry portable and safe for a crew of people to maintain and operate. The turret should be controlled completely wirelessly so that it can be deployed in a dangerous area, and allow the operation team to retreat to a safe area. By setting accuracy specifications, we can set a target range at which the turret will wait to fire. If the target is outside the range that would allow the turret to take an accurate shot, the turret can track the target and wait for it to come within range to fire. When the target does come into firing range of the turret, having the turret quickly lock onto the target and fire will ensure the most accurate shot. The maximum projectile distance parameter is set so that we can ensure the turret will be able to fire a projectile with enough force to maintain an accurate shot. The projectile speed parameter also plays a role in accuracy by allowing the turret to adjust its aim, fire, and have the projectile reach its intended target before the target has moved a substantial distance and potentially requiring the turret to readjust its aim and fire again.

The specifications for the range of motion will allow the turret to engage targets in a multitude of positions. The horizontal range of motion will allow the turret to identify and engage targets with a range of motion approximately equivalent to a stationary human. The vertical range of motion will allow the turret to engage targets positioned above and below where the turret is deployed. We have also set pan and tilt speed specifications to ensure that the turret will be able to locate and track targets traveling at sufficient speeds.

Having a magazine for the turret will allow the turret to engage multiple contacts, or fire multiple times at a single contact before having to reload its ammunition supply. We also want to ensure that the turret's magazine can be replaced quickly, allowing an operator to swap it quickly and then retreat back to safety.

Our power usage target of 30W was made so that the turret could be designed to run at a low enough power to allow it to be run on batteries instead of relying on an external AC/DC power source. We also want the portable battery source to allow the turret to operate for a substantial amount of time without needing to recharge or have a new battery swapped in.

Having a quickly deployability time will allow a crew to set up the turret quickly and operate it from a safe area. By designing our turret to be as lightweight as possible we significantly increase its portability by allowing it to be carried by a single person. We want the turret to run without the need of any external wires needed for power or data transmission. This will ensure that the turret can be deployed in remote locations and operated from a safe distance.

House of Qualities

Correlations

Positive	+
Negative	−
No Correlation	

Relationships

Strong	●
Moderate	○
Weak	▽

Direction of Improvement

Maximize	▲
Target	◇
Minimize	▼
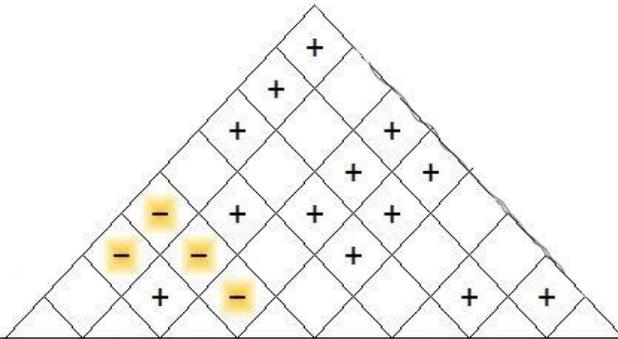
| Column #	1	2	3	4	5	6	7	8
Direction of Improvement	▲	◇	▼	◇	◇	▼	▼	▼
Customer Requirements (Explicit and Implicit) / Engineering Requirements	Control Distance	Fire Range	Power Draw	Operation Time	Accuracy	Weight	Dimensions	Cost
Wirelessly Controllable	●	▽	○	▽	▽	○	○	●
Accurate	▽	●	○	▽	●	▽	▽	○
Multiple Round Magazine	▽	▽	▽	▽	▽	○	●	○
Battery Powered	○	○	●	●	▽	●	●	○
Deploy Quickly	▽	▽	▽	▽	▽	○	○	▽
Target Identification	▽	●	●	●	●	○	○	●
Ease of Use	▽	○	▽	▽	○	●	●	○
Portable	▽	▽	○	▽	▽	●	●	▽

Table 1: House of Qualities

The chart shown above is our House of Qualities (HOQ) table. The HOQ takes customer design requirements and compares them to the engineering design constraints. The level of correlation between the customer's desired specifications and the engineering constraints is shown in the lower portion of the table. Several of the customer's design specifications have little to no impact on the engineering design requirements of the turret. For example, wanting the turret to have a multiple round magazine has no impact on the first five engineering requirements, and will only slightly affect the overall weight of the turret. However, having to account for the storage of multiple projectiles will significantly impact the overall size of the chassis for the turret. Some of the more prominent customer requirements that will strongly impact the engineering design requirements are the need for the turret to be battery powered and for the turret to have target identification. Relying on battery power for our sentry turret will mildly impact the control distance and firing range of our turret as more power may need to be supplied to the wireless communication device for range, and a longer firing range will require more energy to be put into the projectile. Implementing target identification into our sentry turret will most significantly limit the firing range of the turret. Because the turret will be identifying targets with an external camera and imaging software, the range of the turret is now limited to how far the camera can see instead of how far the projectile will be able to travel.

Immediately above the engineering requirements section is the desired direction of improvement. The direction of improvement shows what we, as engineers, want to maximize or minimize about our design. Because of the customer design specifications we want to minimize the power draw so it can power effectively, the weight and dimensions should be minimal to increase portability, and the cost should be minimized to make it financially possible. There are targets set in place regarding the range of fire, operation time, and accuracy, so as long as those standards are met they do not need to be maximized. Lastly, the wireless control range of the turret should be as high as possible so that it can be controlled from a safe distance.

At the very top of the table is the pyramid shaped correlation chart. This section shows how much the engineering design constraints correlate with each other. The first two negative correlations observed when looking at the chart from left to right are between control distance and power draw, and control distance and operation time. As the wireless control distance is increased the total operation time will likely decrease due to increased power demands required by the wireless transmitter. While some positive correlations may benefit our project, there are some positive correlations that have an overall negative consequence. When observing the last positive correlation on the left between the turret dimensions and the overall project cost, as the turret requires more materials to be built, the total cost of the materials is increased.

Project Design Block Diagram
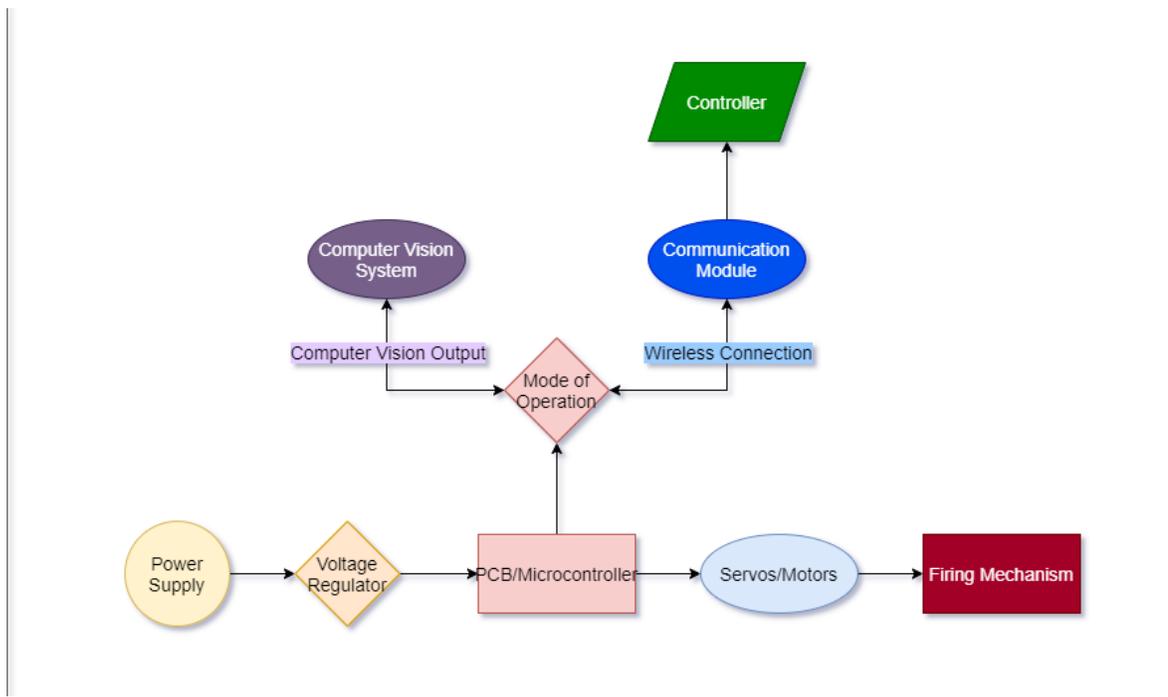
Figure 1: Project Design Block Diagram

As of current, none of the components are designed or purchased. The mechanical parts include the dual axis chassis board, the tripod, and the firing mechanism in which this group may purchase and use a nerf/airsoft gun to be attached or design and build the firing mechanism from scratch. For the motors, this group will be using the servo motors rather than the stepper for the faster speed/greater torque for faster responses to commands, the precision of motion, as well as the variable load due to firing of the ammunition. As of now, the value for the servo appears better than the stepper and will sacrifice the simplicity and cost effectiveness of a stepper for the speed and precision of the servo.

Another aspect of the setup that we have yet to decide is the wireless aspect. Due to the myriad forms of communication it's tough to choose one over another due to each one's benefits and disadvantages. Some of these are satellite communication, Radar, Mobile Telephone Systems (Cellular Communication), Infrared Communication, Bluetooth, WLAN (Wi-Fi), Radio Frequency Identification (RFID), and NFC.

Satellite Communication - This form of communication is based on devices orbiting space in order to have international communication. The cost will vary depending on what resources are used to make the connection utilizing a satellite, such as an open satellite connection or creating one yourself. The upside is that the connection is international and it has high bandwidth. On the other hand the downside is that the distance may cause distortions in signal, high maintenance cost, and it needs to be monitored to check the situation of the satellite.

Radar - This form of communication is mainly used for detecting objects in the distance. It cannot however allow us to communicate with the robot in order to give it instructions. Although we can't directly communicate with the robot we are able to use radar in order for the turret to be able to sense objects and potentially determine to shoot or remain idle.

Cellular Communication - This is one of the most commonly used forms of communication to most people nowadays. The newest development being the 5g which allows fast wireless speeds and connects users worldwide. This would allow us to remotely operate the turret at a further distance given that there are antennas in the area.

Infrared Communication - Infrared (IR) utilizes infrared LEDs that produce light that pulses in a pattern in order to send out a signal. These signals are sent out as pulses from one device to another, where it is received and processed. Usually there is no encryption and the speed of this form of communication is fairly slow. This is an inexpensive form of communication, however it does require a direct line to the target and the range is short.

Bluetooth - This is a wireless communication technology that utilizes radio frequency in order to send and receive data. Bluetooth is able to operate with lower power than wifi but has a smaller range of operation given the devices that are being used to transmit the signal.

Wifi - The most common form of wireless communication to most people is Wifi. Although it consumes more power than bluetooth it has a much farther range. There is also the support of multiple users whereas bluetooth does not have as many.

NFC - Stands for Near Field Communication. NFC is usually used in order to transfer information from close quarters. This allows a more secure process due to the range of transmission. Unlike RFID, NFC is able to allow two way communication.

RFID - Is an inexpensive form of communication similar to NFC. The range of an RFID is farther than that of an NFC even though they are both low power. Although they are similar in nature, RFID only allows communication in one way rather than a bidirectional form of talking.

In the end each form of wireless communication is dependent on the use. If a person requires multiple users on a device to connect them to the internet then wifi might be a thing to consider. When referring to setting up a wireless turret, there are many things to consider. Some of these are whether the turret will be in sight and even the distance which will most likely be the most important aspect. The reason distance will play the biggest role in choosing a form of communication is because a turret may be operating in another are that is hundred of miles away, in that case NFC or RFID won't be a sufficient form of communication

Existing Projects and Products

Designing and implementing an automated Nerf sentry is no new concept and this proposition has been made numerous times through website and video tutorials across the internet. They all involve a similar standing turret that can either be pointed at a target or recognize it, lock on to the target and fire upon it. There have been many senior design projects predicated on this exact concept that involve software implementing color recognition, facial detection, facial recognition, shape recognition and others.

As of currently, automated sentry turrets are used around the world, primarily by military defense in some countries. They are not readily available to be sold in the market to the average consumer. These sentries don't use recognition to determine if friendly or hostile such as it would with facial recognition. Their target identification functions off of motion such as in the U.S. Navy's Phalanx CIWS which contains a search radar that detects if the target's range is increasing or decreasing in relation to the ship. It then checks if the target is able to strike the ship based on its velocity and trajectory.

In South Korea, the SGR-A1 is deployed along the Demilitarized Zone to assist troops using a system that integrates surveillance, tracking, firing and voice recognition. South Korean Firm DoDAAM showed the Super aEgis II which can lock onto vehicles or humans with thermal imaging, unaffected by night or weather conditions, up to 3km away. Israel has implemented something similar, deployed on the Gaza border but requires a person to give input to fire.

Now all of these automated sentry turrets are beyond the budgeting that our BRO-NS sentry would be given. The research time and technology are ultimately too deep and sophisticated to understand with the scope of this project along with the fact that almost all the information regarding these technologies' designs and implementations are most likely classified.

Estimated Project Budget

Component	Cost
Portable Battery Charger	$30
Screws and fasteners	$10
MCU	$50.00
wire spool kit	$15.99
motors (4-8ct)	$40
Three leg tripod	$12.99
voltage regulator	$10.00
Misc. circuitry components	$15
Materials for Chasis	$25
TOTAL	**$209**

Table 2: Project Budget

The parts list above shows the cost analysis of the most crucial components needed to build our remote controlled sentry turret. Due to the current electronics part shortages occurring throughout the United States, some parts may need to be substituted for more expensive components or may be subject to elevated shipping costs from foreign countries. Due to the cost of circuitry components becoming cheaper the higher volume they are purchased at, and the very low requirement of components for our design, the circuit components needed for the project will have to be bought at a low volume premium.

Other factors to consider for the cost of our project are the cost of using a custom circuit board. Our PCB will house whatever MCU(s) we decide to implement in our design, as well as the numerous voltage headers required to split up the input DC voltage into the various values we will need to supply other circuit components. The single most expensive component of our project will be the MCU or the 'brains' of our turret. Using only one MCU would significantly cut costs of our project, but we are unsure if it will have enough computing power to control every aspect of the turret. Most likely we will have to utilize two separate MCUs in the turret; one to control the motors and actuators used to aim and mover the sentry, and the other to perform the image processing needed to identify targets.

How we choose to power our turret will also play a key role in the overall cost of our project. There are many relatively inexpensive options for rechargeable batteries that are used for small form factor remote control devices such as high performance RC cars and planes. However, the performance of these batteries is highly dependent on the quality of the battery itself. The cheap mass produced batteries found in consumer grade RC products represent the lower quality, lower cost alternatives; while enthusiast grade, high output rechargeable batteries represent the higher quality, higher cost alternative. Depending on the construction of the batteries and the composition of the battery electrolyte material, the more premium options could cost upwards of three times as much as the more affordable options.

If it is required by the project specifications, a custom in-house designed DC-DC voltage regulator can also be constructed. This would require the purchase of additional resistors and capacitors to step-down or step-up to the voltage required by the miscellaneous electrical components used in the system.

One of the largest unknown costs for the project is the cost of the materials needed for the chassis. Because we want the turret to be as lightweight as possible the main options for materials would be plastic and aluminum. Constructing the chassis from aluminum would greatly improve the durability of the turret at the tradeoff of aluminum costing substantially more than PVC or other plastic materials. Because we want our turret to be cost effective, exotic materials such as carbon fiber are not being considered.

Project Milestones

Task	Assignee	Due Date
Preliminary Project Research	All Members	9/30/2021
Assign Roles for Research and Design	All Members	9/30/2021
<u>Senior Design 1 Assignments</u>		
Initial Document	All Members	9/17/2021
Updated Divide and Conquer	All Members	10/1/2021
60 Page Draft	All Members	11/5/2021
100 Page Draft	All Members	11/19/2021
Final Draft	All Members	12/7/2021
<u>Senior Design 1 Component Research</u>		
Motors, Actuators, Servos		11/23/2021
Wireless Communication Methods	Daanish	11/23/2021
Power Delivery	Kyle	11/23/2021
Circuit Design	Juan / Kyle	11/23/2021
Microprocessors	Juan	11/23/2021
Firing Mechanism	Ross	11/23/2021
Camera System		11/23/2021
Computer Vision Technologies		11/23/2021
Chassis Design		12/17/2021
Wiring Diagram	Kyle	12/17/2021
Research Programming Language for MCU		12/17/2021
PCB Design	Juan	1/14/2021
<u>Winter Break</u>		
PCB Mockup	Juan / Kyle	1/14/2022
Chassis Mockup		1/28/2022
Begin Writing Code		1/28/2022

Senior Design 2 Deadlines		
Begin Order of Parts	All Members	1/28/2022
Assemble Custom PCB	Juan / Kyle	2/11/2022
Assemble Turret Controls	Daanish / Ross	2/11/2022
Build Prototype	All Members	3/11/2022
Finish Coding of Turret		3/25/2022
Test Prototype	All Members	4/1/2022
Finalize Assembly	All Members	4/1/2022
Presentation	All Members	TBD
Final Report	All Members	TBD
Final Presentation	All Members	TBD

Table 3: Project Milestones

Throughout the course of Senior Design 1, our group will be researching various technologies to incorporate into our project. We will then make a decision as to which technologies we think would help us best complete our project given our design specifications. It is our goal to have our custom PCB design almost completely finished before the end of the semester, and we want to have a good idea as to how we would like our chassis to look.

Because our Senior Design 1 course takes place in the fall, we have three weeks off of classes for winter break. During this time we would like to put any finishing touches on our custom PCB and we will start gathering materials to use for our chassis. We are anticipating that the PCB design will require the most time to develop and troubleshoot therefore we are starting the design early. We also want to develop some of the programming that we will use for the MCUs to control the various motors and other electrical components in our turret.

For Senior Design 2, most of our deadlines are centered around the assembly of our turret and ensuring all of the parts are in working order. The last month and a half of Senior Design 2 will consist mostly of testing and presenting our design.

Decision Matrix

	Cost	Knowledge on Topic (1-10) Worst to Best	Difficulty (1-10) Easy to Hard	Educational Goals	Sponsorship
Stirling Engine	$500 or more	4	8	Learning to create energy through heat and rotational energy. Along with monitoring and using solar tracking	no
Wireless Turret	$200	6	5	Learn to remotely control machines while solving ways to utilize energy and ammo efficiently	no
Plant Watering System	$150	7	4	Learn to automate and design an electrically efficient watering system for plants	no

Table 4: Decision Matrix

The matrix shown above shows the decision making process we did in order to go about choosing our project, cost being the major factor. The stirling engine cost was significantly higher due to the design requirements. In order to build a sustainable engine that can handle high levels of heat it would need to be made out of metal. While the thought would have been any metal can be used we had to use aluminum, due to the design of utilizing the magnets to not only generate electricity but to also reduce the amount of friction in the system.
The second project idea we had was the wireless turret. The cost of the turret is significantly lower due to its design function being mostly on the software and hardware aspect allowing us to use lighter and cost efficient material to test them.

The third project we had was the plant watering system. The cost for this project would be the lowest overall due to its main function being able to water plants. This allows us to build a smaller enclosed system that is able to water the plants, thus being cost efficient. Overall the projects that were in consideration had a learning curve to them because we were not familiar with the concept or the process of creating them. The stirling engine had the most cost with the least amount of knowledge on the topic with very little resources on how to fully build an efficient model. On the other hand our knowledge on the idea of the turret and watering system was a bit more, and there are a lot more resources on the topics. Paired with the cost efficiency these two were our top choices. The wireless turret gave us more control on design as well as allowing us to create our own project with less knowledge on the subject giving it a bit more complexity. Hence the reason for us choosing the remote turret.