Computer Controlled Aiming & Tagging System

Concept Generation

EML 4551C – Senior Design – Fall 2011 Deliverable 1

Team # 2

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Project Problem Statement

The Air Force Research Lab at Eglin is researching the accuracy of their Computer Controlled Aiming and Tagging System. The C-CATS program is used in Eglin's missile guidance systems to locate and lock on to possible targets, and Eglin needs a system to test the ability of their C-CATS.

Our project deals with creating a non-destructive missile tagging system that will mark the center of the would-be impact and explosion on the target. Our mechanical system will only be tested statically for fire latency, shot accuracy and shot dispersion. Because no system like this exists, Eglin wants to make sure our system is accurate and stable enough in a static testing scenario before dynamic testing occurs, therefore it will only be tested and analyzed from a stationary firing position, leaving the dynamic testing to future teams. Our system needs to be tested to be within specifications because it will eventually be testing accuracy and ability of the full C-CAT system.

In order for Eglin to get the most accurate results for their tests, we have restraints that we must adhere to so our system will be up to standards. The most important constraint is that our marking system can traverse the entire forward hemisphere of the projectile to mimic the same ability of the real missile. It also must be able to turn the 360 degree azimuth in under 1 second. This is a feature designed for the future dynamic testing so the C-CATS program would have enough time to locate a target and position our aiming system before impact. The resolution of the motors must also be less than 1 degree so the motion of the marker is as smooth as possible. Another restraint is that the system must be less than 50 pounds because the rigging system has a weight limit, so our system cannot exceed that limit or it cannot be tested. Our last major constraint is our system will be controlled by user input and must be safe to fire and will not have any unwanted discharges.

Our system will be statically tested, firing at targets at a range of 25 meters, using manual user inputs as its targeting system. The manual input will act in place the RF and optical sensors, as they give only directional outputs, therefore our system should easily take commands from them in the future, when the programming language is compatible.

Figure 1: Destructive smart bomb with C-CATS style imaging program

Existing Systems

There are no current non-destructive tagging systems that we were able to find used specifically for missile guidance.

Controllers

All of the controllers being looked at will have the ability built in to be a motor controller also. They need to be able to turn the motor on and off, but also need to tell the motor how many steps it has taken and receive feedback so the controller knows where the motor is at all times. This is for accuracy and calibration reasons.

Option 1 – Arduino Board

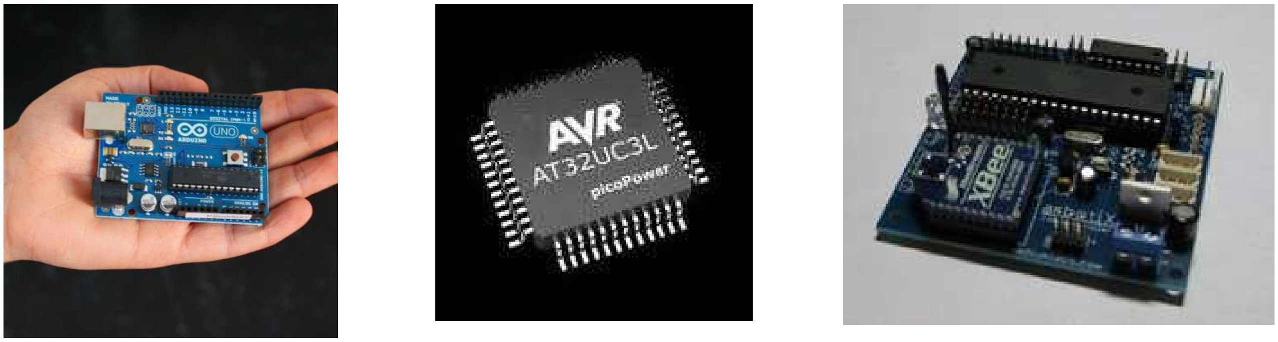
Since we are going to use servo motors we will need a controller board to control the motors to do what we want them to do. One type of controller that is being considered is the Arduino board. It is a platform used for prototyping for any application. The Arduino board is an open-source platform; therefore, it uses very flexible hardware and software that can be easily modified to fit any given specifications. The micro controller on the Arduino board is programmed by using the Arduino programming language. It uses USB, XBee, or Bluetooth links for communication. Therefore, it can be used wired as well as wirelessly. The max operating frequency of the Arduino is 150 Hz when wired. Furthermore, the Arduino allows control of the analog, digital and PWM from the computer. The cost of the Arduino board is approximately $30, making it easily feasible to obtain within the budget constraints.

Option 2 – Atmel AVR

Another type of controller being considered is the Atmel AVR UC3. It is a 32-bit high performance micro controller. The C series of these micro controllers is currently used in high performance and automotive applications. This micro controller, like the Arduino board, can connect via USB. The Atmel uses 128 KB of flash memory and it operates at a max operating frequency of 66 MHz. This is more accurate compared to the Arduino board due to the higher frequency. This micro controller also has wireless capabilities using Wi-Fi or RF modules that can be connected to the micro controller. However, this controller is priced way outside our budget, around $6000.

Option 3 - ArbotiX Robocontroller

The final type of controller being considered is the Arobotix Robocontroller. It is another high performance micro controller. The ArbotiX Robocontroller is specifically used to control robots using Bioloid servos. Although that is the ArbotiX's specific design, it is also used to control servos in higher end, more complex robots. It has a max operating frequency of 16 MHz. It has the ability to be used wirelessly but, the Xbee chip is sold separately from the micro controller itself, proving this to be a more expensive option. The ArobotiX also connects to a computer for programming using a serial connection. A way around this is to use another separate chip called an FTDI basic breakout. This allows the serial connection to be replaced with a 5V connection or a USB connection. The controller cost is $100 and the FDTI and Xbee chips cost $14 and $22, respectively, making this a slightly more expensive option.



(a) (b) (c)

Figure 2: Possible controllers. (a)Arduino, (b)Atmel AVR, (c)ArbotiX

Motors

The desired characteristics of the motors that will be used to determine a final type of motor are a reasonable cost, high torque for rapid change of direction, feedback capabilities, and the accuracy of the positioning mechanism. As of now, we have not determined how much will be spent on motors so for now a reasonable cost would include anything below $300 per motor. A high enough torque for a rapid change in direction will be calculated when a final gun selection is made, however our mechanism does need to be able to traverse the entire forward hemisphere in less than one second. We will also require certain feedback capabilities in order to know the positions of the motors in order to program them correctly. Finally, the accuracy of the positioning mechanism is critical to ensure the barrel is on target. A motor with a low azimuth resolution, less than one degree, is needed to make sure the barrel traverses its path smoothly and stops on target.

Option 1 – SMART Motors

Smart motors in Figure 3a below are used in a variety of engineering applications. These motors are "smart" because they are stepper motors that have a built in motor controller. Also the smart motors provide a high torque which is necessary for pivoting and moving the barrel of the gun up and down to ensure that the barrel can cover the whole forward hemisphere. Since these types of motors come with the vital parts already installed, the price to attain these types of motors is expensive and could deplete the projects budget.

Option 2 – Servo Motors

Servo motors in Figure 3b below are also a considerable option to provide motion to the barrel for the tagging system. These types of motors are commonly used in many engineering applications and simple projects, which make them easy to attain. The torque needed to move the barrel will not be an issue due to the fact that the motor can be sized to the project's specifications for torque. Servo motors do not come with installed motor controllers, so we will need to purchase a controller that has that ability, or purchase a pre programmed motor controller board to attach to the motor.

Option 3 – DC Motors

These motors, shown in Figure 3c, are very durable and usually cheap motors that would be able to provide the motion and torque the system would need. The major problem with these motors is that there is no way to get any position feedback from them. DC motors really only have an on and an off button and their velocity can be adjusted, but they do not have any "steps" or any system that allows the motors to rotate to a specific position. This is a major drawback to these motors, and for our system purposes, they will probably not be utilized.

(a) (b) (c)

Figure 3: Motor Selection. (a)SMART Motor, (b)Servo Motor, (c)DC Motor

Rating:
0: Lowest Score
5: Highest Score

		Concepts					
		Smart Motors		Servo Motors		Basic DC Motors	
Specifications	Weight	Rating	Score	Rating	Score	Rating	Score
Cost	30%	0	0	3	0.9	4	1.2
Position Accuracy	15%	4	0.6	4	0.6	1	0.15
Response Time	20%	4	0.8	3	0.6	1	0.2
Additional Components Required	10%	5	0.5	2	0.2	1	0.1
Overall Size	25%	3	0.75	2	0.5	3	0.75
Total	100%		2.65		**2.8**		2.4

Figure 4: Motor Selection

Power Supply

The C-CAT system will need to have a power source to run all of the motors and electronics on board. Since the system has a weight restriction, the power supply must be light weight, it must allow the system to still move when it is plugged in, and it also must provide sufficient power to run the whole system. The three power systems that fit this build the best are rechargeable batteries, a small movable generator, and a wall plug.

The rechargeable batteries are a good small, compact solution to our power supply. They are relatively cheap, costing anywhere from $20 to $40, and would allow our power system to sit directly in our entire mechanism. They would add almost no weight to the system and would keep it completely cordless. The downside to these is usually the more they are used, the faster they lose their charge, and usually the power in a rechargeable battery greatly affects the performance of controllers, so they will need to be closely monitored.

The second power system is a small generator. These would be able to supply all the power we would need, and some even have the ability to adjust their power output. A generator would not directly affect the weight of the system, but it does restrict its mobility because the system must always be in reach of the power cord. Two major downsides to generators are their cost ranges from $99 to $350 for the small ones, and fuel for the generator must be bought and readily available.

The third power system is a standard wall plug. This would be great because wall plugs are universal and could be found anywhere and using them are incredibly cheap because it only costs the amount of buying the cord. But the wall plug has major drawbacks too because even though plugs can be found anywhere, they can usually only be found inside or near buildings, and our system is a live fire system that will definitely not be fired inside, and probably not be fired near any buildings. Even is a plug was close enough, it would greatly inhibit the movement of the system.

Rating: 0: Lowest Score 5: Highest Score		Concepts					
		Rechargeable Battery		Generator		Wall Plug	
Specifications	Weight	Rating	Score	Rating	Score	Rating	Score
Cost	25%	2	0.5	2	0.5	5	1.25
Power	15%	3	0.45	5	0.75	3	0.45
Size	20%	5	1	1	0.2	5	1
Maneuverability	25%	5	1.25	2	0.5	1	0.25
Ease of Use	15%	3	0.45	3	0.45	3	0.45
Total	100%		3.65		2.4		3.4

Figure 5: Power Supply Decision Matrix. Rechargeable Batteries were selected

Tagging System

No matter how accurate the controllers or motors or electronics, if the tagging system is not accurate, it all goes to waste. This is why this section puts so much emphasis on getting the right parts to assemble the most durable and accurate tagging system.

Paintball Guns

There are many paintball guns in the market, but the marker needed for this system needs to be rugged enough to stand long uses, yet light enough so the motors will be able to maneuver it around. The Tippmann A5 and the Empire Invert Mini are the main markers under consideration. The A5 is one of the most popular paintball guns because it is a very tough and heavy-duty gun, and it is also highly modifiable. The ability to easily modify it is a big plus because it will need to be mounted to the moving motors and stay in place. The downside to this gun is it is relatively heavy and will need a good deal of modifying to make it so the electronic systems can run the gun. The Empire Mini on the other is really small and light and completely electronic. This is good for keeping the weight of the system down and allowing the controllers to interact with the gun. The downside to this gun is that it is not easily modifiable and will be tough to get mounted to a bracket on a motor.

Barrels

The marker needs to be as accurate as possible so when fired on our system, it will accurately represent the position our system was trying to hit. One way to increase the accuracy of a paintball gun is by modifying its barrel. After much research and reading, a hammerhead barrel is the brand that the system will use. These barrels are generally longer than most standard barrel, which allows for further and more accurate flight. They also are known to keep consistent pressure on the paintball as it travels through the barrel, and this consistency of pressure translates in consistency in ball flight from shot to shot. The barrels are also rifled which puts spin to the balls, therefore increasing its aerodynamics, the distance and accuracy, and the consistency of ball flight.

The two barrels under consideration are the Hammerhead Freedom Fighter and the Hammerhead MoFo. The Freedom fighter is the cheaper of the two, and it costs $59. The problem with it is that it is only compatible with the Tippmann A5 gun, so choosing this barrel would pigeon hole us into that particular gun. The MoFo is their carbon fiber barrel, and is able to fit any gun. The carbon fiber keeps the barrel light weight and it is impervious to extreme weather changes. Its downside is that it costs $139, over twice as much as the Freedom.

Figure 6: MoFo barrel showing rifling and carbon fiber design

Paint

Paintballs will be used as the point of interest in this project to measure the dispersion and accuracy of the tagging system during the static testing. During each simulation the residue left behind by the paintballs will be measured to ensure the tagging system is operating at top performance as it cycles through numerous targets via the user inputs. In our concept two different types of paintball are being considered to be used as measuring instrument for the tagging system.

Figure 7

The Standard paintball shown in Figure 7 seem to be the optimal choice since it is the most commonly used ammunition in the standard paintball gun. The positive about these paintballs are that they are easy to get a hold of and relatively inexpensive. The major drawbacks to the standard paintballs are that they do not have a very long shelf life, they are known to burst in the gun and cause a jam, they are very inconsistent in their flight path, and the paint runs after it hits a target, making it tough to see the exact point of impact. The other ball being considered is the RAP4 G.O.L.F. paintball. It is dimpled like a golf ball which provides a much more aerodynamic flight for longer distances and a more accurate shot. They also are filled with powder, which leaves a very distinct dot at the point of impact. This will help increase accuracy when measuring our dispersion.

Ball Feeding

The stock hoppers on paintball guns are usually very slow, bulky, and can get clogged very easy. Therefore, some alternative ball feeding mechanisms are being looked at. The standard hopper uses gravity to help feed the balls, so if turned upside down, it would not work. Also, because it is bulky and sticks out, it greatly affects the center of mass of our rotating gun and puts much unneeded stress on the motors. The alternative is the q-loader. It is spring loaded, so it allows the balls to be fed against gravity, and through some fabrication, it would be able to have an extended hose, allowing it to be mounted off of the gun, taking that extra weight off of the motors.

(a)

(b)

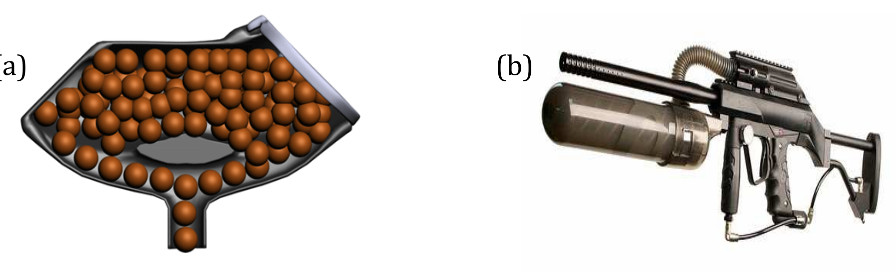


Figure 8:

(a)Standard Hopper

(b)Q-Loader

Pressure System

The three main types of compressed gasses used in paintball guns are carbon dioxide, compressed air, and nitrogen. Carbon dioxide is the cheapest of the three and the most widely used. However, when fired repeatedly using carbon dioxide the gun can get very cold and over time destroy internal parts causing more expenses to be spent on maintenance and upkeep. Also the internal conditions of the CO2 can fluctuate greatly due to external temperatures and conditions. Generally a CO2 tank when used in cold weather will not have enough pressure in the tank to operate properly and vice versa for a hot weather.

Compressed air is more expensive than CO2 but the initial cost outweighs the future maintenance that will not be needed. Compressed air, shown in Figure 9, is also more reliable, light weight and is easily attainable; all that is needed for refilling it is an air compressor. However, when the compressed air is stored in the tank, so is the moisture in the air. This moisture goes through the gun when fired and over time can cause problems internally. Keeping the gun well maintained and clean is one way to prevent this from occurring.

Figure 9

Finally, nitrogen (N2) is also a very reliable, light weight source and costs generally a few more dollars to refill than compressed air. Both compressed air and nitrogen are considered High Pressured Air (HPA) and can be stored in the same tank as shown in Figure 9. Nitrogen maintains a more stable pressure in paintball tanks under different ambient temperatures. Also, pure nitrogen (N2) contains no moisture so there are no issues about damaging the internal parts of the gun over time.

General Concepts

Concept 1

Concept 1 is based around the combination of an aerodynamic shell incorporated with a platform extruding from it, shown below in Figure 10. This platform is where the gun will be mounted to move around the forward hemisphere. The shell will house all the electronics and gear. The pros of this design are that it is compact and streamlined and allows a direct path for the hoses and wires to be run inside the housing. The cons are that there will stress on the platform mount where the gun sits and the wires and houses might get tangled while the gun rotates.

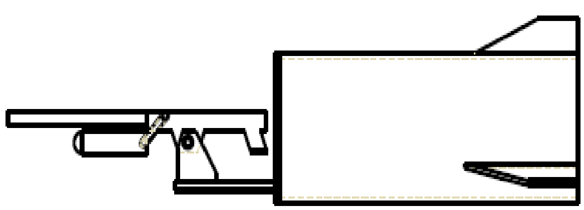


Figure 10

Concept 2

Concept 2 is based around the turret used on the B-25. It uses a dome to house all the electronics and gear, shown below in Figure 11. The gun is mounted on a bracket, which is mounted on a rod that is rotated by a set of gears. The turret will be able to rotate horizontally as well. The pros of this design are that the entire system is enclosed so none of the electronics and hoses will get tangled when spinning. The cons are that it is not streamlined and not easily attached to a cable for future testing.

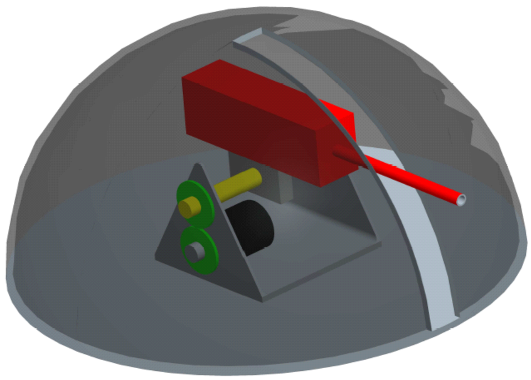


Figure 11

Conclusion

After looking at all the parts that will put together the tagging system, we now have a good idea of what components we will be implementing. The next step is to go in and mathematically look at everything from the movement of the motors to the stresses on the firing system and housing components. Every part needs to be checked and make sure it will not critically fail during its use. Also, system dynamics will be examined to look at the motion of the gun as it rotates through the forward hemisphere and also the flight path of the projectile to make sure that it will be able to reach its target without the force of gravity affecting the flight.

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