Proposal

Autonomous Tracking Robot

ECE4007 Senior Design Project

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TABLE OF CONTENT

Executive Summary

The autonomous robotic tank will demonstrate target acquisition, following, and targeting capabilities. The tank will use a combination of IR motion sensors, an ultrasonic proximity sensor, and a webcam to autonomously track and fire at a human target. The IR sensors will recognize a target has approached the robot and will be responsible for alignment. The webcam will be linked with a color tracking program running on the eBox 2300, which will enable the tank to track a moving target from side to side. The ultrasonic proximity sensor will be used to read the distance between the target and the robot, controlling when the robot should move forward. Before a full scale prototype is built, it is useful to build a small scale model to show the technology's capability. It would be expensive to acquire an actual military tank to test the capability of the listed technologies in achieving full autonomy. The final unit including all engineering and production costs is estimated to be about $3,000. The expected outcome of the project is that the robot will successfully align itself, follow, aim the turret, and fire at a moving human target.

Autonomous Tracking Robot

1. INTRODUCTION

The desire to minimize casualties in warfare led to the invention of the unmanned ground vehicle or UGV. UGVs are controlled either autonomously or remotely by crew members from a safe distance. Most, however, are remotely controlled and are primarily mounted with firearms. Taking this technology one step further, the DK-3 senior design group will be building a scaled down autonomous tank. Not only will autonomous tanks minimize casualties, they will also increase military strength without the need for additional manpower.

1.1 Objective

The autonomous robotic tank will demonstrate target acquisition, following, and targeting capabilities. These capabilities will display the underlying technologies behind the application of autonomously controlled vehicles to tanks. The tank will use a combination of IR motion sensors, an ultrasonic proximity sensor, and a webcam to autonomously track and fire at a human target.

1.2 Motivation

Autonomous tanks would be primarily marketed towards the military and national defense. Before a full scale prototype is built, it is useful to build a small scale model to show the technology's capability. It would be expensive to acquire an actual military tank to test the capability of the proximity sensors, the IR motion sensors, and the web camera running the color tracking program, in achieving full autonomy. In building a small scale version of a potential prototype, these technologies can be demonstrated to interact together successfully with the embedded system, as well as provide accurate and effective autonomous tracking. In successfully building this small scale robot, the military would be motivated into building a full scale prototype for an autonomous tank.

1.3 Background

Autonomous vehicles are still in a phase of heavy research and design. Although other industries have interest in them, their primary interest is the military. Congress has mandated "It shall be a goal of the Armed Forces to achieve the fielding of unmanned, remotely controlled technology such that [...] by 2015, one-third of the operational ground combat vehicles are unmanned," in Section 220 of the National Defense Authorization for Fiscal Year 2001. DARPA offers millions of dollars in various autonomous vehicle tests through the DARPA Grand Challenge to advance the development of autonomous vehicles [1]. Thus far, the military has developed autonomous vehicles that gather information, transport goods, or work for extended durations, but they have not produced a fully autonomous battle tank [2].

Technological Components

The key building block needed for autonomous vehicles are sensors. Passive infrared heat sensors are used to detect motion and ultrasonic proximity sensors are used to determine the distance of an object from the vehicle. Without these crucial components, the vehicle is blind to its environment and is essentially useless.

2. PROJECT DESCRIPTION AND GOALS

The project engineers will modify a 1/16th scale, radio-controlled (RC) tank to be mounted with and controlled by a mini computer. The computer will attain input data from various components. IR motion sensors will be used to detect the movement and relative location of the target. An ultrasonic proximity sensor will determine the distance of the target from the tank. A web camera will utilize a computer tracking algorithm embedded in the computer. The goal for this project is to have the robot perform the following set of actions:

- Detect a moving target and rotate to face the target
- Follow the moving target
- When target stops, adjust itself to a specified distance from the target
- Adjust turret to aim at target
- Fire a projectile

The final unit is estimated to have a total cost of approximately $3,000. This price includes parts and labor cost. It will be primarily targeted for use by the military.

3. TECHNICAL SPECIFICATIONS

Proposed autonomous tracking battle tank specifications are outlined in Table 1. Table 1.

Autonomous Tracking Vehicle Specifications

Attribute	Criterion	Specification
Target Firing Range	Need distance between turret and target	3m
Mounting Size	Need space for mounting eBox 2300	115 x 115 x 35 mm
Cone of Accuracy	Radial distance from target	6°
Motion Sensing Range	Need distance between each sensor and target	5m

The tank will adjust its distance from the target to a range less than 3m before it will fire the projectile. If the distance is greater or less than this range, then the tank will move accordingly. The tank will require an open area of 115 x 115 x 35 mm to mount the eBox 2300. If there is not sufficient space, then a mounting platform will need to be fabricated. For firing the projectile, the tank will have a cone of accuracy within 6° from the target's center. The maximum distance that the tank will sense motion will be 5m away.

4. DESIGN APPROACH AND DETAILS

4.1 Design Approach

The autonomous tank consists of four main components: the computer, the sensors, the controller and the tank. Figure 1 shows a block diagram of the control flow.

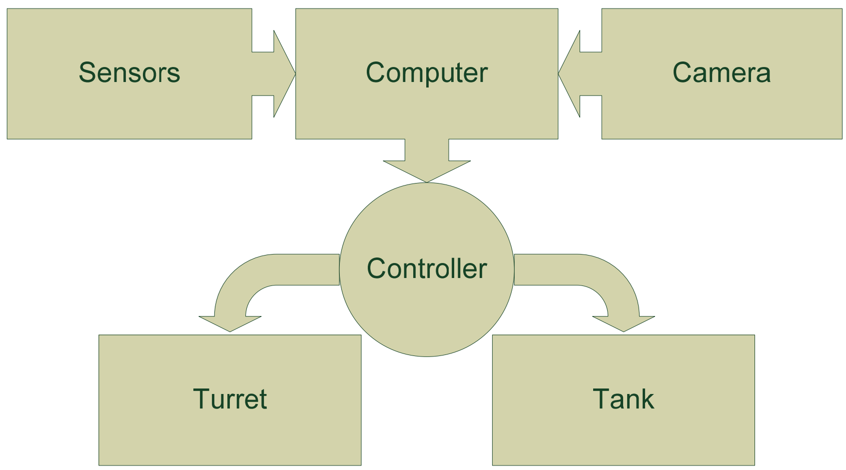

Figure 1. Control flow diagram.

Tank

The specifications for vehicle are summarized in Table 2.Table 2. Vehicle Specifications [8]

Attribute	Specification
Type	German Tiger
Scale	1/16th
Size	18”x9”x8”
Turret Rotation	320°
Firing Range	25m
Ammunition	Airsoft BBs
Reload	Automatic

Sensors

The sensors used will be four Panasonic AMN23111 IR motion sensors, one Panasonic AMN21111 spotlight IR motion sensor, one ultra sonic distance sensor and a Microsoft VX-6000 webcam. The sensors will be arranged as shown in Figure 2. The position and facing of the AMN23111 sensors are shown in grey. The position and facing of the AMN21111, VX-6000, and SRF04 are shown in blue. The VX-6000 and SRF04 will be mounted on the turret while the other sensors will be mounted directly on the tank’s body.

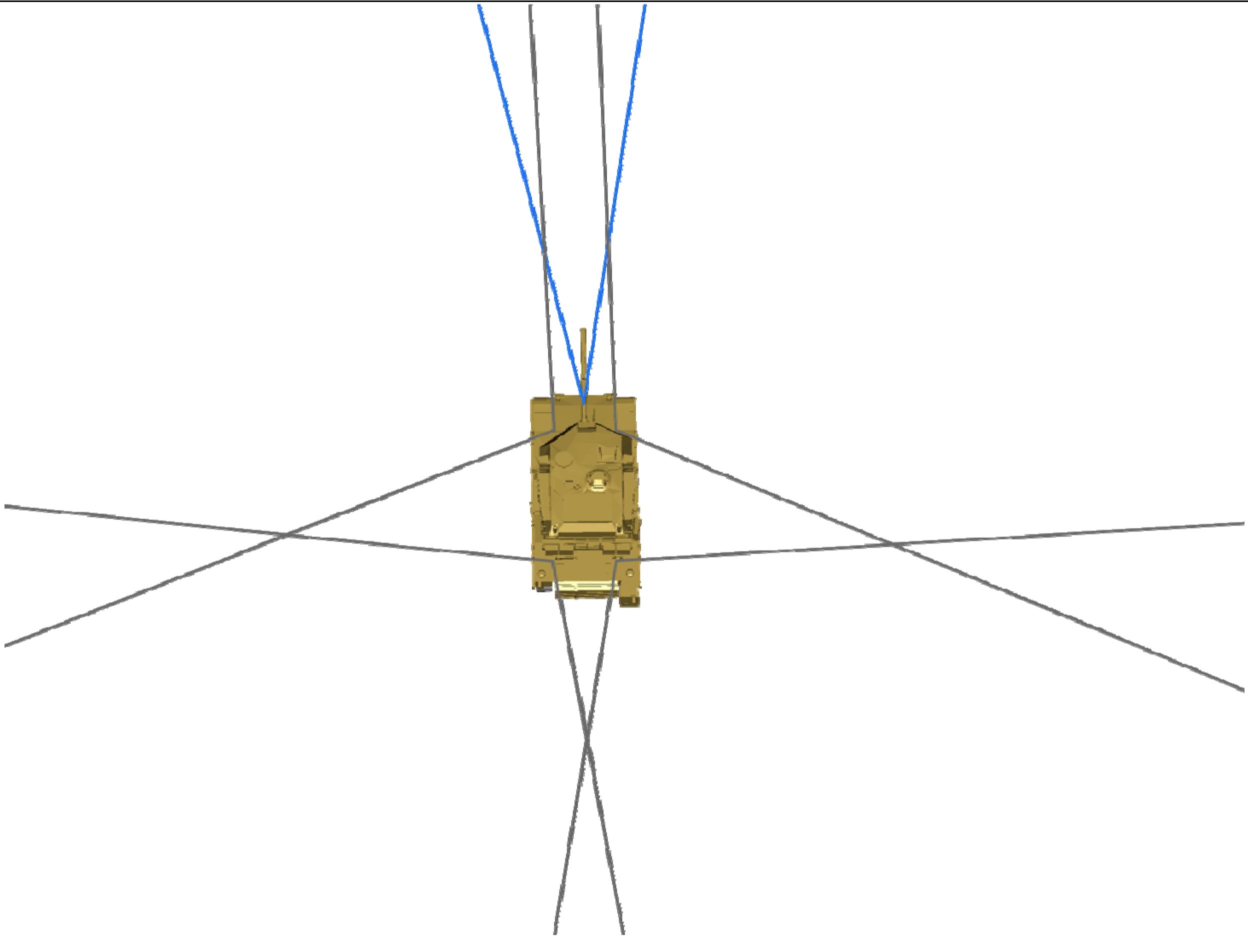

Figure 2. The sensor arrangement. The position and facing of the AMN23111 sensors are shown in grey. The position and facing of the AMN21111, VX-6000, and SRF04 are shown in blue. The VX-6000 and SRF04 will be mounted on the turret while the other sensors will be mounted directly on the tank's body.

The AMN23111 and AMN21111 will be mounted on the tank's body. They were chosen as IR motion sensors so the tank wouldn't detect movement in all directions when it moved. The VX-6000 and SRF04 will be mounted on the turret to allow the tank to track with it when the body is immobile. The VX-6000 runs on USB 2.0 and captures up to 30 frames per second [10]. The

SRF04 can detect a 3cm diameter stick less than 2m away [9]. Table 3 contains sensor specifications.

Table 3. Sensor Specifications

Attribute	**AMN23111** [3]	**AMN2111** [4]	**Ultra Sonic** [9]	**VX-6000** [10]
Horizontal Range	100°	38°	45°	71°
Vertical Range	82°	22°	45°	71°
Number of Detection Zones	64	24	N/A	N/A
Detection Range	10m	5m	3cm-3m	N/A
Output Voltage	4.5-5.5V	4.5-5.5V	0-5.5V	N/A

Computer

The eBox 2300 is an embedded system that will be mounted on the back of the tank. The eBox has a 200MHz Vortex86 SoC CPU with 128MB of onboard SD-RAM [7]. It will take input from the sensors and use that information to control the tank. All of the sensors, except the VX-6000, produce digital outputs and will connect to the digital input of the Phidgets 8/8/8 board, which connects to the computer. The kit has 8 analog inputs and 8 digital outputs [5].

Controller/H Bridges

The S11-3A-EMF-HBRIDGE H-bridge will be used to control each individual motor on the tank, as well as the control for the turret. There are two motors that control the tanks movement.

The H-Bridge can control a total of two motors, so it is well suited for the application. The H-bridge can produce up to 3A of current, and a maximum of 27.5V for motor control. The individual motor specifications will need to be tested in the laboratory before the team determines what settings to use with the H-bridge [6].

Algorithm

Upon detecting the target, the tank will turn to the closest edge of the quadrant in which the target was found. The tank will begin to sweep the quadrant by turning until the AMN21111 on the front of the tank detects the target. Then, the VX-6000 will be used to track instead of the motion sensors as the tank will be approximately facing the target. The webcam will use a color tracking algorithm, which has not been specified. If at any point the VX-6000 loses sight of the target, the tank will return to the start of the algorithm, searching for the target with the four AMN23111s. Once the target is in the SRF04's range, the distance from the tank to the target can be determined. The tank will then approach the target, correcting via webcam input as necessary, until it becomes 1.5m from the target. Upon reaching that distance, the tank will halt movement and attempt to aim the turret at the target. If the target moves out of the SRF04's range, the tank will return to approaching it. Once the turret is aimed at the target, it will potentially fire at it. The conditions for the tank to fire and whether it will actually fire has yet to be determined.

4.2 Codes and Standards

The purpose of the autonomous tank being proposed is to demonstrate the underlying technology behind autonomous vehicles can be effectively applied to full scale tanks; thus, it is a custombuilt product with no intention of mass production and has no standards imposed upon it. The full scale tank, however, would have to be standardized for mass production and would have other specifications determined by the military.

4.3 Constraints, Alternatives, and Tradeoffs

Alternative Vehicle

The initial vehicle choice for this project was a remote controlled helicopter, but due to payload carrying constraints and cost constraints, the RC tank was chosen instead.

Time Constraints

The deadline for the finished product is mid-April, which implies most parts will have to be integrated with off the shelf parts. It also implies that the development of movement and tracking algorithms using image processing or triangulation will have to be simplistic or non-existent. Unless a previous color tracking algorithm can be obtained, the one used will be simple, tracking a uniquely colored region.

Cost Constraints

The primary constraint upon the design was cost because the budget for parts, excluding those already owned, is a maximum of $403. The quality of the RC tank, sensors, and controller had to be reduced to maintain affordability. The number and type of sensors and the size of the tank were also reduced.

Size Constraints

Because the cost constraints determined the size of the tank, size constraints were placed on the rest of the parts as they are to be mounted on the tank. The German Tiger tank was chosen as it had the largest space behind the turret to mount the Ebox.

Targeting Constraints

If the target can move faster than the tank can turn, then the tank may not be able to reliably track it. When the tank is tracking using motion sensors, it will have a slower ability to track as it will have to stop to take in sensor readings.

5. SCHEDULE, TASKS, AND MILESTONES

A description of the detailed schedule, tasks, and milestones is included in the Gantt Chart included in the Appendix. The column titled names describes who will be working on each specific task. All writing assignments will be done by the team as a whole. The majority of the hardware applications will be handled by Andy and Nate. The majority of the software applications will be handled by Chris and Wink.

6. PROJECT DEMONSTRATION

6.1 Final Demonstration

The autonomous vehicle will show its effectiveness in a live demonstration. The vehicle will be placed in a room at an arbitrary orientation. After the vehicle is powered on, a person (the target) will enter the room and walk to any location they desire. The vehicle will detect the motion and track the target until it is within firing range, as shown in Figure 3. The tank will then shoot a small, plastic projectile at the target.

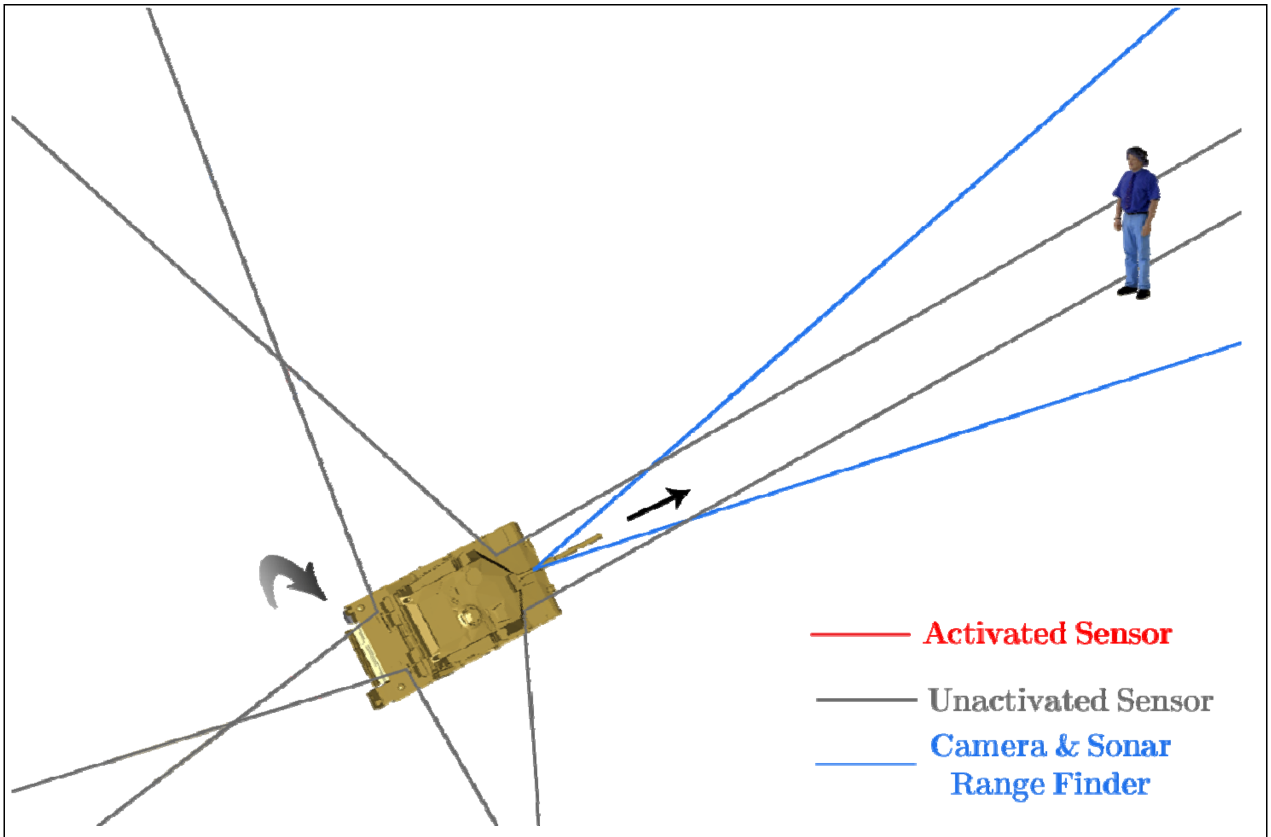

Figure 2. Tank rotating to face its target using motion sensors.

This will demonstrate the specifications of the project by showing that the vehicle is capable of autonomously:

- Finding a target in a room using only sensors
- Tracking the target using a video camera
- Maintaining distance from the target using an ultrasonic sensor

6.2 Incremental Testing

Prototypes of the vehicle will be tested in incremental stages.

Stage 1

The first stage will be to test each of the three actions listed above separately. This will be done by isolating each action and testing whether the software responds to a stimulus from the target correctly. All four of the infrared sensors will be tested separately to determine whether they can be triggered properly by the presence of the target. The video camera based tracking will be tested by aligning the vehicle so that it is already facing the target. The vehicle will then move toward the target, constantly correcting its course using video data. The ultrasonic sensor will be tested by placing the vehicle a known distance away from the target. Multiple readings will be taken at each distance to test the precision for the sensor.

Stage 2

The second stage of testing will be integrating two consecutive actions. First the vehicle will be placed facing directly toward a stationary target. The vehicle will travel at the target using the camera for course adjustments and stop after the ultrasonic sensor determines that it is within firing range. After these two actions are working together effectively, the first action will be incorporated into the test; the vehicle will have to locate the stationary target within the room before tracking it.

Stage 3

The final stage of testing will require the vehicle to track a moving target. The vehicle will first locate the target using the infrared sensors and then track and follow the target using the camera and ultrasonic sensor. The target will then move such that it is out of view of the camera so that the vehicle will have to locate it using the infrared sensors again. The vehicle will also be tested by having no targets in the room and a target that enters the room after a delay.

7. MARKETING AND COST ANALYSIS

7.1 Marketing Analysis

The autonomous tracking robot is being used to demonstrate the capability of the applied technologies to successfully track and fire at a target. This project is being done before any full scale prototype to save both time and money. For this reason the robot will not be sold commercially. The product is targeted towards the army, aiming to draw a contract for implementing a full scale prototype. Since this product is being built as a 'pre-prototype', some of the parts were borrowed from Georgia Tech. The product is also being built to 1/16th scale of an actual autonomous tank. If a full scale prototype were to be built, the cost would be considerably higher.

7.2 Cost Analysis

Development of the full scale prototype would require an outside contract from the army. The cost analysis will focus on if a company were to contract this team to build this small scale prototype to demonstrate that this system is a viable option in a full scale application. The estimated workload of each group member including all documentation, lecture attendance and outside meetings is estimated at 80 hours. The prices in Table 2 describe the actual costs in producing the small scale prototype in an industrial or corporate setting, meaning donated and borrowed parts are included in the price. Profit per unit is estimated to be $770, or approximately 20%. The selling price is based on the fact that the item would be mass produced as opposed to being used to attract a contract to build a full scale prototype.

Table 4. Cost Analysis of Selling One Unit at $4000

All Materials [3]-[10]	$500
Assembly Labor	$200
Testing Labor	$120
Fringe Benefits, % of Labor	$100
Overhead, % of Matl, Labor & Fringe	$500
Sales & Marketing Expense	$1000
Technical Support Expense	$300
Amortized Development Costs	$650
Subtotal, All Costs	$3370
Selling Price	$4000
Profit	$770

The costs for materials were based upon the bulk price for the items, if available. The assembly of the product would likely be done by a technician, at an average salary of $20 per hour, taking approximately 10 hours total. The testing would also be done by either a technician or an entry level engineer at $20 per hour, taking approximately six hours [11]. The development cost for producing 10 units was based upon an approximate per unit development cost of $65. The remaining costs were approximations based on the cost of the materials and labor.

8. SUMMARY

The vehicle, all of the sensors, and a dual H-bridge have been ordered, but they have not yet arrived. An eBox 2300, Phidgets 8/8/8 interface kit, Phidgets LCD with digital and analog input/output, and a 7 inch touch screen LCD screen have been acquired. The physical parameters of the project are still being explored, such as sensor placement and attachment method, as well as placement of the eBox and power supply on the vehicle. The eBox is currently being interfaced with a Microsoft VX-6000 web camera that will be used to perform target tracking. As soon as the infrared sensors arrive they will be tested using an oscilloscope to measure sensor range and strength, they will be interfaced with the Phidgets LCD board’s analog inputs.

9. REFERENCES

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10. Appendix A: Gantt Chart