Project Proposal for Parking Lot Monitoring System

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***Abstract*—Commuter students at Tennessee Technological University in Cookeville, TN, frequently face difficulties to find open parking spots in lots during peak hours of the school day, which causes tardiness to class to be a common occurrence. Due to current products on the market either being very expensive or not fully feasible or effective for Tennessee Tech's parking lots, an in-house parking lot monitoring system designed by students in Tennessee Tech's College of Engineering is proposed to provide a more cost-effective solution. This project will require interdisciplinary collaboration between teams from the Departments of Electrical and Computer Engineering, Computer Science, and Mechanical Engineering while under the direction of the Naval Sea Systems Command (NAVSEA) in Dahlgren, VA.**

I. Introduction

Nearly every commuter to a college campus has faced something similar to the following scenario at some point: You have just arrived onto campus, and you have about 10 minutes to get to class. You drive to the parking lot closest to the building that your next class is in. It looks like all of the spots are filled, but you hold onto the slightest hope that there is an empty spot somewhere amidst the sea of cars. You drive around in circles, wasting precious seconds for you to walk to class. Other cars keep darting around you in the same situation as you all play a frantic version of musical chairs, but instead with parking spaces. You look up at your car clock to see that it is already time for your class to start. You are late.

Commuter students, defined as enrolled students who do not live in on-campus housing, make up approximately 85% of university students [1]. Unfortunately, this same scenario, this so-called "parking problem," has played out to arguably thousands, if not millions, of these students nationwide, prompting a never-ending stream of frustrations and complaints. This "parking problem" is a perennial pain that has plagued particularly college campuses from the East to West Coasts since the 1950s, and it is an issue that makes students and faculty very impassioned and even embittered [2]. For example, a 2020 survey of 533 students at Truman State University in Kirksville, Missouri, found that 86.4% of respondents believed that parking is a priority issue that should be addressed by their university administration with 64.7% saying that it is difficult to find a spot to park that is close to campus [3]. At many schools, this "parking problem" is fueled by a disproportionate ratio of drivers to parking spots, such as the University of California, Los Angeles (UCLA), which sees 72,000 people on its campus a day but possesses only 23,000 spaces to accommodate to students, faculty, and staff [2]. At other universities, administration and staff see their "parking problem" not as a lack of available spaces but rather as a lack of awareness of available spaces. At the University of Tennessee, Knoxville, students have filed petitions such as one titled "Help STOP the University of Tennessee Parking Crisis" that has garnered over 1,600 signatures, but on the other hand, the staff at UT Parking and Transit Services see it instead as a "get-to-know-where-the-parking-areas-are crisis" [4].

Students at Tennessee Technological University in Cookeville, Tennessee, are not immune to our own "parking problem" on campus as many commuters continually experience the same situation formerly mentioned at the beginning of this section. Commuters would rather not risk being late to class and driving around in circles hoping a spot would open up, yet it can be very difficult to gauge if there are any available spots before driving through a lot. We believe that Tennessee Tech's "parking problem" is not really a lack of parking spaces but more so a lack of awareness of available parking spaces, admittedly some being more inconvenient than others. Thus, we propose to design a parking lot monitoring system that utilizes sensor technology to track and frequently update the number of available and filled parking spots so that students can know the occupancy of different Tennessee Tech parking lots in real-time. The data from the sensor technology would be displayed on a mobile application that students can download to view real-time statistics and previous history of parking lot occupancy, as well as on a ground-level display board.

In this project proposal, we will formulate the problem by examining background information, specifications, constraints, and current solutions to articulately define the objective and to justify the need for our proposed solution. We will then propose our solution for a parking lot monitoring system and detail its infrastructure and interface, unknowns and obstacles, measures of success, and its need. Subsequently, we will list out the resources and requirements needed to design, implement, and test our system as well as the anticipated budget, timeline, and personnel.

II. Identified Problem

In this section, we will define and formulate the problem by examining background information, identifying specifications and constraints including standards and externalities, looking at current solutions that solve similar problems, and justifying the need for this project.

A. Background Information

Tennessee Technological University in Cookeville, Tennessee, has a student population of 9,902 students (including both undergraduate and graduate) as of the Fall 2022 semester [5]. Tennessee Tech sells five colors of permits to students: Green (residential for on-campus residence halls), Teal (residential for Tech Village apartments), Red (commuter), Purple (commuter), and Accessible [6]. There are numerous students at Tennessee Tech who live in off-campus apartments or houses, so many students purchase either the cheaper Purple passes to park in the parking lots on the far outskirts of campus or the more expensive Red passes to park closer to the main buildings on campus, the latter being the more popular option. As of May 2021, out of the 5,762 parking spots on campus, there are 2,388 Red spots (as compared with 735 Purple spots), and many of the Red parking lots are infamous for filling up very quickly and having little to no available spots throughout the day [7]. Commuter lots such as the one behind the Angelo and Jennette Volpe Library (nicknamed the "Library Lot"), the one between the Hooper-Eblen Center and Tucker Stadium (nicknamed the "Stadium Lot"), the one south of Robert and Gloria Bell Hall, and the one across the street from Pennebaker Hall typically have much more limited availability due to their close proximity to buildings on campus as compared with the Red lots near the Intramural Fields on the west side of Willow Avenue or the one next to Foundation Hall. Although these lots would be considered more inconvenient for students with Red passes (since this requires students to cross Willow Avenue and to walk nearly the entirety of University Drive), the two Red lots in between Tech Village and the Intramural and Baseball Fields rarely get filled during the school day, leaving scores of available parking spots for commuter students, according to a personal interview with Callie Harris of the Parking and Transportation Office at Tennessee Tech. However, many students are not aware of these lots, prompting the Parking and Transportation Office to install signage notifying students regarding the availability of parking spots across Willow Avenue in places such as the Stadium Lot in October 2022.

Although there is not a shortage of available parking spots for commuters, due to the prevailing mentality of wanting to get a parking spot as close to one's classes as possible, a majority of students believe that there is a "parking problem" on campus. Students every single day face the same problem outlined in the Introduction: It is very difficult to gauge if there are any available parking spots prior to entering some parking lots, and finding a spot when the lot is already filled could lead to tardiness to class. Trying to find a parking spot that is very close to campus, especially during peak hours of classes, particularly in the mornings, can be seen as a gamble, especially when one is pressed for time. Often, instead of parking in another lot, students will park illegally, which could cause obstruction for facilities and maintenance and potentially for emergency services. Students would find great benefit in having a mobile application or a display board that indicates parking lot availability to plan ahead where to park. We foresee students using this system to determine the availability of spaces in conveniently located parking lots, and the mobile application will spread more awareness about lots that are further out from the center of campus and have generally higher availability.

B. Specifications and Constraints

1) Specifications: The parking lot monitoring system shall collect data and provide information regarding parking spot availability to students. The function requirements include:

(a) System shall not obstruct any parking spots on campus in a way that would not allow a person to park in a given spot.
(b) System shall not interfere with parking traffic on campus in a way that would cause traffic to worsen.
(c) System shall not permanently store images.
(d) System shall not record videos.
(e) System shall operate during parking enforcement hours of 8:00 a.m. - 4:30 p.m.
(f) System shall have a system of sensors to get count of vehicles present in parking lots.
(g) System shall include a second system that can monitor ground truth to measure accuracy of vehicle counts compared to primary system.
(h) System shall have accurate vehicle counts within ±5% of the ground truth's counts.
(i) System shall have a re-calibrate function in the event that sensors are returning inaccurate counts not due to external factors (e.g. weather, physical damage).
(j) System shall have protection against inclement weather (e.g. rain, snow).
(k) System shall have outdoor signage to indicate parking availability to people searching for parking on campus.
(l) System shall have a mobile application for people wanting to check information about availability of parking on campus.
(m) System shall have notification posted on mobile application about potential decreased system accuracy during inclement weather.
(n) System shall have notification posted on mobile application about dangers of driving while using a mobile device as well as its illegality in Tennessee on app startup.
(o) System shall have notification posted on mobile application if system is not fully operational due to system malfunctions (e.g. parts of the system are damaged).
(p) System shall have mobile application display additional chart displaying average parking availability over operational times of day.
(q) System shall, at a minimum, perform its intended function in ideal conditions (i.e. clear weather)
(r) System shall have detailed documentation about the system's design and operation so future owners of the system

can easily make adjustments to and maintain the system.

2) Standards: There are multiple standards that provide additional constraints to the parking lot monitoring system, including:

- The National Fire Protection Association (NFPA) 70 and 70E Electrical Codes and Standards will be used to ensure electrical safety of the system, especially since this system deals with electronics and testing of electronics [8][9].
- The NFPA 70 section 600.34 Photovoltaic (PV) Powered Sign will be used for proper sign design and safety (Equipment, Cords and Cables, Grounding, Disconnecting means, and Battery Compartments) [10].
- Solar Equipment Standards specified by the Clean Energy States Alliance (CESA) including use of equipment and installation will be used which may impact choices of hardware and design aspects when powering the other needed equipment for the system [11].
- A Network Communication Protocols will have to be chosen which will influence design in terms of what hardware and software have to be used.
- Tennessee Code Annotated § 55-8-199, more commonly known as the Tennessee Hands Free Law, prohibits the act of holding a cellphone or mobile device using any part of one's body as illegal, in which only hands free devices are to be used while driving a motorized vehicle [12]. Taken into effect in July 2019, this state law raises ethical implications with regards to the possible usage of our mobile application while driving by students, which may cause a need to address some type of safety feature for the project to either educate or protect the user against misuse of the app related to the law.

3) Externalities: While there are both the stakeholder specified constraints and standards specified by governments and organizations that must be followed, there also needs to be consideration of other external factors or unintended consequences which include the following:

- Safety
  - There is an apparent concern for safety as the end project should include a mobile application that will be used to check parking lot availability. This could lead to the misuse of the app via using the software while driving which is inherently dangerous and also against the law in Tennessee, unless the used device is hands free [12]. Therefore, solutions to prevent the user from doing this would have to be considered, and potential remedies could include disabling the software based off how fast the user is moving or creating a notification to the user on opening the app, reminding them of the dangers and legality of misuse of the system.
- Economic
  - While the project, seen to completion, should see a benefit to students and/or staff on campus, there will be a need to maintain the system to guarantee its continued operation. This would include having a maintenance team and resources to monitor and fix any issues to the system during its operational time which could include systems losing power, damage to the signage, sensor resets, etc. These issues would require not only good documentation of work done and resources used for the project, but also a detailed maintenance plan for whoever is responsible for the system in the future in order to be able to easily make repairs or changes.
- Longevity
  - There may be cause for concern in the late future if the project is not inherited by anyone to maintain which could be caused by either lack of confidence or need in the system or departments not having the resources necessary to maintain it. Therefore, there should be consideration for having an "out of order" type notification to users of the system to let them know when the system is not operational (whether temporary or permanent).

C. Current Solutions to Similar Problems

The use of sensors to track parking availability is an issue that has been tackled before. The following are a few consumer available examples including descriptions on their implementation.

- ParkingDetection has created a camera system for monitoring parking lots. It monitors spots in real time and can look at as many as 400 spots at a time. It also features remote configuration and accessibility from a web browser for lot management [13].
- Smart Parking has created a system of in-ground, surface-mount, and overhead sensors to monitor parking lots and garages. In-ground sensors require drilling into the ground but offer high accuracy. The surface-mount sensors are designed are similar to in-ground but for other surfaces unlike concrete that aren't structurally sound (and can be placed above instead of below). The overhead indicators do go above lots, but also have LED lights included which change color based off the availability of the lot [14].
- All Security Equipment sells a number of parking barriers. They are designed to be ground-mounted at parking lot entrances, and require either payment or identification to get into the area with arm prices range from $1,800 to 40$k [15]. While it may not offer any data on parking availability, something similar could be adapted to take in info on cars moving in compared against total lots to get usable data.
- There are cameras currently on the market with the ability to detect vehicles on the device itself. These cameras are decently priced, with a 4k resolution camera with vehicle detection priced at one hundred twenty dollars.
- Currently, most parking garages and some parking lots are managed with a combination of motor-controlled "arms"

and either ticket dispensers and scanners or pass-card readers and motion detection.

D. Need for Proposed Solution

In the previous section, there are solutions that exist that do address the issue of tracking the number of available parking spots in a parking area. Some solutions are geared more toward implementation in parking garages. Those that are suited for outdoor parking lots are very expensive, especially considering that Tennessee Tech has over 5,000 parking spots across at least a dozen parking lots of varying layouts. In the past, the Office of Parking and Transportation has examined potential electronic systems to enforce parking passes in these lots, but these systems have shown to be extremely costly. Creating an in-house solution to a parking lot monitoring system will provide a solution that is not only cost-effective but also is created by Tennessee Tech engineering and computer science students. Tennessee Tech is mostly well-known for its College of Engineering, so by having engineering and computer science students design a parking lot monitoring system complete with sensors, artificial intelligence, a mobile application with an effective UI/UX design, and other technologies while being able to collaborate together, solve problems, and work with actual customers in industry and stakeholders.

III. Proposed Solution for Parking Lot Monitoring System

In this section, we will provide a brief overview of our solution to a parking lot monitoring system along with potential design approaches, identify unknowns and obstacles that may arise over the project's duration, list the measures of success for each specification "shall" statement, and analyze the broader impacts that this system may have.

A. Solution Overview and Potential Approaches

1) Sensor Technology: This system will utilize sensor technology to collect data with regards to parking occupancy (as listed in the next subsection), and the following sensor technologies have been identified for potential use in this project:

- Visual Sensors/Cameras
  - A visual sensor, or camera, would allow for the framing of visual images, which would then be processed. These sensors would visually monitor the lot, allowing for the entire contents of the lot to be known.
- Pneumatic Tubes
  - A pneumatic tube is a system with low power consumption that observes spikes in pressure when a vehicle goes over a pressurized tube. This sensor would only be able to detect when a vehicle passes over it, making this sensor designated only for monitoring entrances and exits of parking lots.
- Laser Sensor
  - A laser sensor consists of a device that projects a laser beam towards a target and receives the reflected light. Usually, this sensor is used to measure a distance, and thus could be used to see if a car is close or not. It would only be able to detect when a vehicle passes a given location.

These sensors may be powered with solar power or a battery that has a set finite life. These sensors will also be equipped with some form of wireless communication protocol to transmit data to an external server for processing.

2) Data Collection and Processing: The sensor technology will be used to collect data about parking availability and then send that data to an artificial intelligence program for processing. The Artificial Intelligence (AI) could count the number of available vs. unavailable parking spaces and further differentiate between objects in parking lot such as cars and motorcycles. Although this approach may be more precise, because of the presence of motorcycle lots on campus that are very close to main buildings on campus, which in turn causes motorcycles parking in regular parking spots a very rare occurrence, recognizing the difference between cars and motorcycles may not be needed to show students the likely number of available parking spots in a regular commuter lot. An alternative would to be to count the number of passenger vehicles (cars, trucks, SUVs, etc. but excluding motorcycles) in that are currently in a parking lot and then subtract that number from the number of actual Red parking spots in that lot. This reasoning comes from the fact that the number of parking spots in a lot is constant, so it may be more simple and effective to count the number of cars and compare that to the number of parking spots. The only caveat is that if this system were to expand to all lots, then this approach would require the count of parking spots to be stored and then updated whenever rezoning or construction occurs.

After data has been processed, the AI program could then return information such as available spots, unavailable spots, likeliness of finding parking for current time, and likeliness of finding parking at a given time, all of which can be displayed on the mobile application or physical digital signage.

Data processing will be done before reaching application, and there are two potential methods of calculating the data: either at the visual sensor (for total cars in lot or total available/unavailable parking in lot) or on the server (statistical probabilities of lot availability, total cars in lot, total available/unavailable spots). Processing data at the sensor nodes will be faster but at the risk of data being more prone to environmental noise, whereas processing data in a cloud server may be more accurate but at the cost of speed.

3) User Interface: The information collected by this system will be presented on a mobile application. The students will first login to this app using their student identification numbers and passwords. The app will then have features that will allow students to be able to view what parking spots are available in the lots that this system will be implemented in, as well as other analytics and history regarding parking spot availability.

A sign will also be implemented displaying the total number of available parking spots. This sign will be placed in an area that will not impede traffic or be too distracting for drivers on campus.

Both the mobile application and the sign will output data to users during the operational hours of 8 a.m. to 4:30 p.m., which are the hours that parking is enforced on campus. Although data may still be collected outside of these times, both the app and the sign will stop outputting data. The app may pop up a notification indicating the lack of parking enforcement while the sign may simply turn off.

4) Physical Areas of Implementation: Because this project is to be designed and implemented within a two-semester school year, it will be more feasible to concentrate efforts to getting a fully functioning system that works for two parking lots on campus. After speaking with the Office of Parking and Transportation and conducting an informal survey for student input, the parking lot behind the Volpe Library ("the Library Lot") and the parking lot behind Tucker Stadium ("the Stadium Lot") have been identified as the two most strategic parking lots to first implement.

The Library and Stadium Lots are the two largest Red parking lots on campus, with the Stadium Lot having 518 Red parking spots and the Library Lot having 313 Red parking spots [7]. Due to their proximity to multiple buildings on campus, these two parking lots are often considered the most competitive lots to obtain a parking spot. The Stadium Lot is seen as a strategic lot to first implement our system due to the limited number of entrances, the vast number of parking spots in a rectangular enclosure, and the potential ability to mount visual sensors on poles surrounding Tucker Stadium. The Library Lot is considered to be strategic due to its popularity among students for a parking spot. Also, after conducting an informal survey regarding potential features and areas of implementation of a parking lot monitoring system with 86 student responses as of September 25, 2022, the Library and Stadium Lots were the two most selected lots at 75 and 64 votes, respectively [16].

B. Unknowns and Obstacles

Various obstacles may arise over the course of this project. Among these are the following:

- Illegal actions
  - Vandalism of this system acts as an unknown in this project. It is nearly impossible to completely defend against vandalism. It is uncertain whether this would happen whatsoever.
  - Illegal parking in areas that are not official parking spots as well as parked vehicles that occupy multiple spaces may make cause inaccuracies in the count.
- Weather
  - Inclement weather may damage the system in unforeseen ways.
  - During inclement weather, it is unknown if the system will properly perform. Snow may cause excessive glare for the visual sensors, rain and fog may also cause glare. High winds, cold weather, and lightning may also affect the sensors.
- Time Constraints
  - Time constraints will be managed by limiting the scope of lot monitoring to 1-2 lots and by rigorously scheduling several milestones over the course of the project.
- Device Specifications
  - If the visual sensor approach to the issue is pursued, it must be verified that the number of pixels needed to detect a car is accounted for in the camera model chosen as well as camera placement. In addition, the device must be properly shielded against rain in order to provide results with some accuracy during inclement weather.
  - If a pneumatic road tube is the pursued application, it must be verified that the system can be regularly maintained.
  - If a laser sensor is used, it must be verified that it would continue to function properly in inclement weather.
- Infrastructure
  - We plan to ask Information Technology Services (ITS) to set up a server. There may be network obstacles which will require training on said networks.
  - Mounting the sensors and signage will likely require the team to access campus resources for safety.
- Accuracy
  - The system will need to achieve a 95% accuracy based on the total number of parking spots in the lot that the system is monitoring. For example, for the Stadium Lot with 518 parking spots, a 95% accuracy translates to a 26 parking spot tolerance. Since the mobile application and digital signage will be provided to students at little to no cost, a wider tolerance can be accepted. In addition, during peak times of the day, parking availability may rapidly change: If there are 5 spots available at 8:55 a.m., there is a high likelihood all 5 spots may be filled up by students aiming to head to their 9 a.m. class. Thus, the number of parking spots available can be touted as a likely number, allowing for a wider tolerance especially in large lots. Technology to accomplish this accuracy must be pursued and verified, but there is little room to test the accuracy of a technology, and hence thorough research must be done.

C. Measures of Success

The measures of success for the parking lot monitoring system are as follows:

- Visual Inspection
  - System shall not obstruct any parking spots on campus in a way that would not allow a person to park in a given spot.
  - System shall not interfere with parking traffic on campus in a way that would cause traffic to worsen.
  - System shall operate during parking enforcement hours of 8am - 4:30pm.

- System shall have outdoor signage to indicate parking availability to people searching for parking on campus.
- System shall show data relevant to parking availability.
- System shall have detailed documentation about the system's design and operation so future owners of the system can easily make adjustments to and maintain the system.
- System shall have a system of sensors to get count of vehicles present in parking lots.
- System shall show data relevant to parking availability.
- System shall have notification posted on mobile application about potential decreased system accuracy during inclement weather.
- System shall have notification posted on mobile application about dangers of driving while using a mobile device as well as its illegality in Tennessee on app startup.
- System shall not permanently store images. System shall not record videos.

- System shall include a second system that can monitor ground truth to measure accuracy of vehicle counts compared to primary system.
  - Ground truth system will be tested to determine the detection of a vehicle is determined. Min range (laser sensor) or min pressure (tube sensor) tests will be performed.
- System shall have a re-calibrate function in the event that sensors are returning inaccurate counts not due to external factors (e.g. weather, physical damage).
  - Sensors calibration will be tampered with manually then re-calibrated numerous times to proper function status.
- System shall have protection against inclement weather (e.g. rain, snow).
  - Rough (strong wind and rain),mild(light drizzle), and ideal(clear) weather conditions will be simulated. System performance should remain stable during ideal conditions.
- System shall have a mobile application for people wanting to check information about availability of parking on campus.
  - Parking lot/vehicles parked data will be compared to the data from the ground level and upper level systems. Both data numbers should match to pass the evaluation.
- System shall save data related to number of cars in parking lot at given times.
  - Vehicles will be driven into random spots in the designated parking lot to verify camera detection and data is correctly transmitted.
- System shall have mobile application display additional chart displaying average parking availability over operational times of day.
  - Hourly usage statistics will be saved and compared to the application statistics to verify numbers match.
- System shall, at a minimum, perform its intended function in ideal conditions (i.e. clear weather)
  - Rough,medium, and ideal weather conditions will be determined from local weather stats. System will be tested or simulated at those conditions to verify performance.
- System shall have accurate vehicle counts within ±5% of the ground truth's counts.
  - Ground level data and upper level data will be compared. Upper level vehicles parked data should be within the designated tolerance listed above. Ex) Ground truth detects one hundred cars have entered to lot than the upper level system should detect 95-105 vehicles parked.
- System shall have notification posted on mobile application if system is not fully operational due to system malfunctions (e.g. parts of the system are damaged).
  - Simulation of components not fully functional or completely not functional will be done. Visual verification of notification on mobile application will be done.

D. Broader Impacts

Inflation in on-campus parking may be a possibility due to the initial cost of installing parking lot monitoring equipment across the university. Though initially it would be relatively high, this cost would progressively decrease over time, which could cause displeasure in the student population. By making wise decisions and only investing in features that are required, we plan to lower hardware costs in order to address this problem. Purchasing an 8k camera system, for instance, whenever it is not required.

Accident rates may go up or down as a result of the parking lot monitoring system's implementation. Students searching for parking spaces would experience less anxiety if the parking software was used properly. However, if the app is utilized incorrectly (i.e., by frequently turning away from the road to look at the app), it may result in more accidents.

To enforce correct parking, the addition of the parking lot system might be used. It might be possible to identify improper parking with future system improvements (i.e. obstruction of two spots). Another improvement to the system might be the recognition of the color parking pass. In this manner, the proper parking pass to the parking zone is obtained.

The addition of the gathered park data might be a fantastic resource for Tech's future growth. Knowing how each parking lot is used and at what time slots is useful information for potential expansion or refurbishment. With this information, Tech management may visually determine whether a lot is underutilized and whether it could be used for another structure or function, or perhaps a frequently utilized parking lot has to be expanded.

IV. Resources and Requirements for Implementation

In order for this project to be feasibly implemented, various components, technology, and testing devices spanning both hardware and software will be needed and within a specific budget, all of which will be examined in this section. The personnel needed in the Electrical and Computer Engineering, Computer Science, and Mechanical Engineering teams and the project timeline will also be covered.

A. Components, Technology, and Testing Devices

Various hardware and software components are needed to implement and test the system, as shown below:

- Hardware
  - Visual sensors that can capture and return data tied to objects located in the parking lots
  - Power supply for visual sensors to maintain sensors powered without much human maintenance
  - Attachment modules for visual sensors to keep sensors stationary when installed
  - Phone/Computer to test system application
- Software
  - Programming software for visual sensor
  - Server allowing for storage of data in database collected by visual sensors
  - Programming software that can pass data from database to application

B. Budget

With similar systems already existing at a much higher price point, this system will have a significantly smaller price point. The budget will contain, but not be limited to the following:

- Visual Sensors/Cameras - $800 (8 pack)
- Road Tube Sensor System - $660 or Photoeye Counting System - $600
- Street Signs - $400
- Database license - $900

C. Personnel

Due to the scope of this project, three teams are required to feasibly design and implement the proposed system: an Electrical and Computer Engineering team leading the project, a Computer Science team working on the artificial intelligence and mobile application design, and a Mechanical Engineering team designing the housing of the system.

1) Electrical and Computer Engineering Team: The Electrical and Computer Engineering (ECE) team will be leading the effort and mainly defining the project. The group possesses a wide variety of skills and experiences which could be helpful for the project. Our team is split between two Electrical Engineering majors Aaron Wilhite and Regulo "Reggie" Garza, two Computer Engineering majors Kester Nucum and Gabriel "Gabe" Laboy, and a Electrical and Computer Engineering double major Genevieve "Eve" Schreiber. This makes a perfectly even split for the team, which will help with splitting up the software and hardware work. Each individual team member has strengths and experiences that could be beneficial to this project.

The ECE Team members bring the following skills and experience to this project:

- Regulo Garza
  - Programming Languages: PLC ladder logic, C++
  - Software Skills: Studio 5000 logix, CX-one, Sysmac Studio, AutoCAD Electrical
  - Hard Skills: Cognex camera setup, Automotive vehicle repair, Machine repair, electrical print design and wiring.
  - Engineering Experience: Co-op as a controls designer engineer at ATC Automation.
- Gabriel Laboy
  - Programming Languages: C languages, SQL, limited Java, JavaScript, CSS
  - Software Skills: Object-Oriented Programming
  - Engineering Experience: Web Design, Database modifications
- Kester Nucum
  - Programming Languages: C++, MATLAB (including Simulink), C, Assembly, Java, R, MySQL, Lisp, VHDL
  - Software Skills: QGIS, LTspice, Git, reStructuredText, LaTeX, UML
  - Hard Skills: Soldering printed circuit boards and programming STM32 micro controllers including the F031K6, L031K6, and L452RE
  - Engineering Experience: Software development with Agile Scrum methodology; modeling and simulation of surface-to-air missile systems and radars, exporting models from MATLAB Simulink, and writing wrappers in C++ (as part of two summer internships at a defense contractor); embedded systems maintenance and testing for water quality sensors (as part of research with a Civil Engineering professor); writing hardware programming labs for Intro to Computer Programming students
- Genevieve Schreiber
  - Programming Languages: C++, MATLAB, C, Assembly, Python, R, VHDL
  - Software Skills: Word, PowerPoint, Excel, LTspice, Git, GitHub, Jira, Agile Scrum, Unix/Linux
  - Hard Skills: Raspberry Pi 3B and Arduino R3 experience
  - Engineering Experience: Interned in embedded systems project
- Aaron Wilhite
  - Programming Languages: C++, PLC Ladder Logic, VBA, MATLAB
  - Software Skills: Word, Excel, LTSpice, AutoCAD, Wonderware and InTouch, Studio 5000 and Factory Talk View Studio
  - Hard Skills: Industrial Controls schematic reading and

wiring, automotive repair experience, Data Acquisition Experience
  - Engineering Experience: Worked a co-op in system integration/controls industry for one year

The skills and experience among all members–as well as their interest in artificial intelligence, sensors, and controls–qualifies the team to undertake this project.

2) Partnerships with Other Disciplinary Teams: Our team will be working with another team of Computer Science (CS) majors at Tennessee Technological University. This team will be assisting us by doing the app development, AI programming, and image processing for the project. We will also be working with a team of Mechanical Engineering (ME) majors to create the housing for the hardware used in this project. Because many aspects of this project require skills that are not considered typically part of the scope of the Electrical and Computer Engineering fields–in particular app development, data analytics, artificial intelligence, and product housing–teams comprising of members from both the CS and ME Departments are needed. The interdisciplinary collaboration between ECE, CS, and ME will not only produce an effective final product but also blur the boundaries between the departments in the College of Engineering to promote further collaboration in problem-solving.

D. Expected Timeline

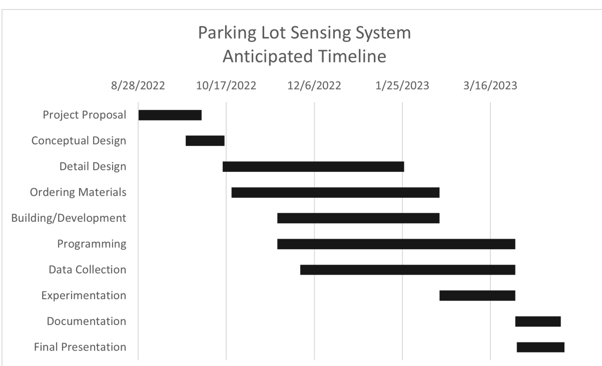

Figure 1. Anticipated Timeline

The expected timeline we plan to follow will be the same as what was presented to us previously. This is an overview of that timeline in chronological order pertaining to our project:

- September
  - Project Proposal Completion
  - Conceptual Design Review and Completion
- October
  - Conceptual Design Presentation
  - Starting Detail Design Phase
  - Starting Sign-off on Work
  - Starting ordering required materials for project
  - Start collecting data for AI
  - Meet with Mechanical Engineering Team
- November
  - Starting Programming for app and the system
  - Start building the app and system (hardware and software)
  - Detail Design Checkpoint 1 and 2
  - Start to meet with Computer Science Team
- January
  - Detail Design Completion
- February
  - Ordering required materials complete
  - Experimentation begins
  - Working prototype app and system mainly complete
- March
  - Documentation, poster, and presentation starts
- April
  - Final presentation starts and is completed
  - Poster is completed
  - Final Documentation is completed
  - All remaining tasks are completed

V. Conclusion

A parking lot monitoring system implemented on Tennessee Tech's campus would provide a very beneficial service to students commuting to campus, and in particular save students precious minutes to get to class on time. Designing and implementation of an in-house solution to this "parking problem" on campus will provide both a more cost-effective system that can be tailored more specifically to Tennessee Tech's needs but also an opportunity for collaboration between departments within the College of Engineering. Creating a parking lot monitoring system that meets the specifications detailed by the customer and stakeholders is feasible to design and implement with the previously mentioned timeline, resources, personnel, and budget. This parking lot monitoring system will have positive impacts on the Tennessee Tech community for years to come.

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