Project Proposal for Parking Lot Monitoring System

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***Abstract*—Commuter students at Tennessee Technological University often face the difficulty of finding available parking in lots during the day. Students from the Electrical and Computer Engineering Department, in collaboration with the Department of Computer Science, will design a ground-based solution that is more reliable than using cameras. With this system, it will be able to cover more parking lots that cameras could not monitor. This is in part due to some parking lots not having the infrastructure to house the cameras in the necessary locations to monitor the lots. This project will be under the direction of the Naval Sea Systems Command (NAVSEA) in Dahlgren, VA. This project is a continuation project from the 2022-23 academic year at Tennessee Technological University [1].**

I. Introduction

There is a widespread belief among commuter students that there must be a more practical approach to solving the ongoing parking problem. The way that students, teachers, and visitors go about their everyday lives could be entirely changed by a technology that offers real-time information on the availability of parking places in particular lots across campus. The tension caused by the never-ending search for a parking spot might be reduced by such a solution, lowering the possibility of students arriving late for classes and campus events.

Implementing a ground-based parking lot monitoring system is a viable option for resolving this long-standing issue. A ground-based solution gives more flexibility than conventional camera-based systems, which may only be able to cover some parking spaces, especially those without surrounding structures for camera location. This ground-breaking technology could be installed throughout several places on the campus, carefully monitoring parking lots with defined entrances and exits to give users the most recent information on parking availability.

The difficulties of using cameras for parking monitoring, the restrictions imposed by nighttime visibility, and security issues will all be covered in the following parts. Finally, the benefits of a ground-based parking lot monitoring system for Tennessee Tech University will be presented. Through this investigation, we aim to raise awareness of the potential benefits of using technology to improve parking for the entire campus community.

II. Identified Problem

A. Background Information

Students who attend Tennessee Tech University in Cookeville, TN, and live off-campus face the same challenge of finding an available parking spot within a reasonable distance from the buildings on campus while staying within student parking lots. These students who commute to campus every day are only allowed to park in certain parking zones depending on the color of their parking pass: red zones (for off-campus students) and purple zones (for purchase by anyone)[2].

Since students are limited to these specified parking zones on campus, students will go back and forth through many of the lots closer to the buildings in hopes of finding available parking. This effort takes time to find a spot that may not even be available in the area a student wants to park in. By taking more time than necessary to find a parking spot, students tend to stay caught up in getting to their classes, which makes them late to class, all due to trying to find a parking spot within a reasonable amount of time. One statement that many commuter students would agree on is that there needs to be a way to know the number of available parking spots for specific lots on campus so students can find available parking within a reasonable amount of time to avoid the possibility of running late to class or other events on campus.

To help students find available parking on campus within a fair amount of time, a ground-based parking lot monitoring system would be a considerable asset to commuter students as it would enable students to know the status of the numerous parking lots on campus and the available number of parking spots in each lot. This solution would also be better suited for Tennessee Tech University's campus as cameras would not cover as many lots due to some parking lots not having buildings or structures nearby that could house the cameras. A ground-based system that covers parking lots with designated entrances and exits can be used on numerous parking lots on campus. By implementing this ground-based solution, students, faculty, and campus visitors would benefit significantly from this system as it would help them find available parking on campus within a reasonable amount of time.

B. Goal of This Project

The goal of this project is to design a proof of concept solution for a vehicle counting system that will keep track of the number of vehicles in a given lot on campus, such as the gravel lot near the Marc L. Burnett Student Recreation and Fitness Center, without the use of cameras. The specific lot mentioned does not offer structures to support cameras to monitor the entire lot, which would hinder students from knowing if there is available parking. Implementing a ground-based system for parking lots with designated entrances and exits would cover a more extensive range of parking lots on campus that may need help finding areas to place cameras to monitor parking lots.

C. Specifications and Constraints

1) Specifications:

- The existing solutions inherited from the previous project, the camera, sign, and server, shall be maintained at their current capability.
- The system shall have a backup power system for the sensor in case the main power supply fails.
- The system shall detect vehicles entering and exiting a parking lot.
- The data collected by the sensor shall be communicated to the server wirelessly.
- The system shall keep a local count of vehicles that enter or exit a parking lot if communication to the server is severed.
- The system shall function at all times of the day.

2) Standards: The following are potential standards and regulations that continue to provide additional constraints.

National Fire Protection Association (NFPA) 70 and 70E Electrical Codes and Standards - This standard is intended to safeguard persons and property from hazards arising from the use of electricity. This standard will be followed to ensure the electrical safety of the system and of the working environment as the team is building and testing the system[3][4].

The International Electrotechnical Commission (IEC) 61000-6-4 - This standard sets requirements applied to electrical and electronics equipment to provide an adequate level of protection to radio services[4]. This standard would set limits on any inductive loops that are to be used.

3) Externalities: During the planning and design phases, it is essential to consider all potential positive and negative externalities that may arise from Tennessee Tech University's development and implementation of the Parking Lot Monitoring System. There is a concern for the safety of pedestrians navigating through the campus parking lots or sidewalks without encountering safety hazards or disruptions caused by the parking monitoring system. The parking monitoring system will comply with the accessibility guidance.

The system could have economic externalities, potentially increasing parking costs for some users, if it implements dynamic pricing based on demand or charges fees for gold, red, or green parking spaces. Also, might include having resources to maintain the system by fixing any problems that occur such as the system losing power, damage to the signage, sensor resets, etc.

This technology can reduce the stress of locating a parking place, lessen the risk that students will be late for courses and events, and improve all aspects of campus life by providing real-time information about parking availability in certain campus lots. This ground-based technology, which differs from conventional camera-based systems in that it allows flexibility in monitoring different lots with marked entries and exits, is appropriate for the campus's varied parking locations.

D. Stakeholders

The Parking Monitoring Sensor System will play a crucial role in the Tennessee Tech community by enhancing the overall college experience for everyone involved. Stakeholders include students, faculty members, visitors, and larger businesses, such as NAVSEA, who would want to implement this system.

Nowadays, parking tracking is a mandatory requirement, especially with the rising student population and the sudden campus construction. Using parking sensors has many advantages, especially for drivers on campus, shopping centers, or airport parking. Drivers benefit by being able to find parking faster and more efficiently, and businesses benefit because employees spend less time finding parking and more time completing their assignments.

In our specific case, NAVSEA is the sponsor for the project with their guidance and specifications. We were asked to implement the parking sensors that will monitor the campus. Also, it might be implemented in the various NAVSEA locations around the United States.

The proposed parking monitoring system has the potential to make a positive impact on all stakeholders. It seeks to address a long-standing issue, enhance campus life, and bolster the university's reputation for innovation and problem-solving. However, it is imperative to carefully plan and consider ethical and privacy implications to ensure its successful implementation.

E. Current Solutions to Similar Problems

For many college campuses across America, parking is one of the biggest daily challenges commuter students face. According to a survey by Mt. San Antonio College that included 1,033 responses, 68% of respondents state it takes 15 minutes or more to find a parking space, with 32% stating it takes more than 30 minutes to find a space [5]. To solve this issue, using ground-based solutions to track the available parking would be a step in the right direction to help students know which areas of campus have available parking spaces. The following examples are just a few possible solutions to help college students find parking on campus.

- Diamond Traffic Products offer road tubes as a method to count cars. Using a road tube as a counter would be a simple and economical option to count the number of vehicles in a lot while also being easy to move around from one parking lot to another [6]. However, a disadvantage of this method on the campus of Tennessee Tech University is that the tube would need to be replaced often as numerous cars enter and exit parking lots throughout the course of a single day. Though simple and cost-effective, the maintenance of this solution would be very frequent.

- Diamond Traffic Products offers inductive loop counters as a more permanent solution. This method is not as portable as the road tube method, as the inductive loop is either installed into or under the roadway's surface [7]. However, this method would be more accurate as it would use magnetic sensors to detect the presence of a vehicle and not detect any other objects, such as pedestrians. This would be a helpful method on the campus of Tennessee Tech University as it would not have to worry about human or animal interference due to its ability to detect the change in the magnetic field.

F. Need for Proposed Solution

As stated in previous sections of this proposal, parking is a widespread challenge on many college campuses across the country, and unfortunately, Tennessee Tech is not immune to this issue. Current solutions to this problem exist; however, they can be costly, require significant maintenance efforts, and use proprietary software. Tennessee Tech would benefit from a student-made solution to achieve a more cost-effective and custom-tailored solution. This is also the problem the previous capstone team attempted to provide a solution to. However, we believe their solution is flawed and needs significant change. Due to the nature of cameras, any situation that could affect visibility will decrease the accuracy of the open parking space count given by the system. This makes their solution potentially highly inaccurate. We believe our proposed solution is superior to the past team's solution. In particular, inductive loops would allow our system to remain online nearly always. The last capstone team to work on this project focused on using cameras to count cars in a lot and to detect cars entering or exiting a lot. We believe cameras are not a good way to count cars entering or exiting a parking lot. The cameras could have difficulty detecting a car in many reduced visibility circumstances, such as when there is a glare, heavy rain, snow, or at night. The inductive loop system would have no issue in any of these situations. This means our system would potentially be much more accurate over time than the previous team's camera solution. This is why we believe there is a need for our proposed solution instead of the past team's solution.

III. Proposed Solution for Parking Lot Monitoring System

A. Solution Overview and Potential Approaches

1) Solution Set
   a) This project's scope is to be a proof of concept of a ground-based sensing system that will be able to track and keep count of vehicles entering and exiting parking lots more reliably than cameras that use visual image processing. Our solution set includes parking lots with designated entrances/exits that are only accessible through those entrances/exits, such as lots surrounded by curbs, sidewalks, or places not meant to be driven on. The parking lots will also have minimal structures to install cameras. For example, the gravel lot near the Marc L. Burnett Student Recreation and Fitness Center. It has designated entrances and exits, is bounded by sidewalks or grass that is not meant to be driven on, and most importantly, does not have many structures to hang cameras.
2) Sensor Technology
   a) A pneumatic tube system with low power consumption observes spikes in pressure when force is applied to it. These sensors could be used to detect how many axles and in turn, how many vehicles will be entering or exiting a given parking lot.
   b) A weight sensor system observes a force applied to it and calculates the corresponding weight. Weight sensors could be used in a similar fashion to pneumatic tubes to measure if a vehicle is entering or exiting a given parking lot.
   c) An inductive loop sensor system would detect changes in a magnetic field that is generated by the system. By driving a vehicle near an inductive loop, the metal from the vehicle would disrupt the magnetic field generated by the system and indicate the presence of a vehicle. These types of sensors have been known to not detect motorcycles due to the size difference between motorcycles and vehicles. This is due in part to having a smaller amount of magnetic material than vehicles.
   d) Laser, lidar, and radar sensors all project a form of light or wave toward a target and, depending on the type, will receive the reflected light or wave. These sensors can introduce problems with different weather conditions such as rain or abundant sunlight.
   e) Magnetic sensors detect changes in the surrounding magnetic field. This could be used to detect if a vehicle is in the proximity of a parking lot or parking space. Magnetic sensors would have to differentiate between random metals, magnets, and vehicles for this system.
3) Data Collection, Transportation, and Processing
   a) Using any of the sensors mentioned above will require transmitting the data they collect. The data will be transported wirelessly to a microcontroller unit that will communicate with the existing server. Wireless communication will simplify any future expansion of the system.

B. Unknowns and Obstacles

There are many unknowns and obstacles that may have an impact on our system, such as the following:

- Illegal actions
  - Similar to the previous capstone team's solution, vandalism of the system is an unknown [1]. We can not guarantee our system will be safe from vandalism because it is essentially impossible to completely protect against all forms of vandalism. We do not know if this will be a problem, but it is a possibility.
  - Theft could occur if someone chooses to steal any part of the system. Attempts to make the system theft-proof will not be able to completely stop a thief in all circumstances. It is unknown whether this is likely to happen.
  - Similar to the previous capstone team's solution, illegal parking could affect the accuracy of the system [1]. People may park in the grass or in a space that is not marked as a parking space. It is also possible that people could take up multiple spaces, resulting in less accurate data.
- Time Constraints
  - Time constraints will limit the scope of the project to a proof of concept system that can be scaled up for use with bigger lots on campus. Time constraints will be handled by scheduling milestones for the project.
- Device Specifications
  - Pneumatic road tubes would need to be properly calibrated and regularly maintained, the extent to which is unknown. There must also be some way of distinguishing people walking over or jumping on the tubes from cars driving over them.
  - Weight sensors would need to be properly calibrated and regularly maintained, the extent to which is unknown.
  - Inductive Loops would need to be properly calibrated and require some maintenance, the extent to which is unknown. This solution would be one of the more efficient solutions as it has the ability to detect objects with a large amount of magnetic material. It is currently unknown how the direction of traffic will be determined using these sensors.
  - Laser sensors would need to be properly calibrated and regularly maintained, the extent to which is unknown. There must also be some way of distinguishing people and cars passing through the laser beam.
- Infrastructure
  - Installing sensors will require the team to get approval from the Facilities and Parking departments.
- Scalability
  - We believe our system is scalable and will cover the vast majority of parking spaces on campus based on our estimates, however, we can not predict the impact of external factors. This could mean that even though our system would work on paper for a certain lot, maybe it can not be installed because there is no good place to mount our sensor, or maybe the facilities department does not want a sensor installed in what we may consider an ideal spot.

C. Measures of Success

To ensure the success of the proposed parking monitoring system, several key measures of success will need to be established. These measures will serve as benchmarks and criteria for evaluating the system's effectiveness. Each Measure of Success will be experimentally validated to ensure the system meets the specified constraints. It's crucial to conduct these experiments to demonstrate the system's reliability and functionality.

The project should function all the time; therefore, the project will be tested to determine if it is operating all the time by keeping track of whether all the parts, including the power source, sensor, and Microcontroller, are constantly functioning to count the vehicles entering and exiting, the parking lot.

Also, the sensor should communicate with the server wirelessly. To validate that, a vehicle should enter or exit the parking lot, and the sensor should show the counting of available parking spots on the server with the updated parking spot availability wirelessly. Moreover, the system should be able to have a local counting of vehicles, meaning the sensor should not communicate with the server and have a local memory that will allow the data of available parking spots and the ability to be incremented and decremented and to be saved in the microcontroller for the sensor. Also, whenever the server starts to communicate wirelessly with the sensor, the data should be updated in the server and saved. Moreover, the system should be able to have a local count, meaning the sensor should not communicate with the server and have a local memory that will allow the data of available parking spots and the ability to be incremented and decremented and to be saved in the microcontroller for the sensor.

D. Broader Impacts/Ethics

Accident rates may go up or down as a result of the parking lot monitoring system. The signage could be a source of distraction for drivers. This could potentially increase the number of car-related accidents on campus. On the other hand, the parking lot monitoring system could reduce traffic and, as a consequence, car-related accidents because fewer people would be searching for an open spot at the same time if the signs indicate that there are few open spots. If used properly, students will be more knowledgeable about parking availability on campus and have a reduced level of anxiety. With the implementation and upkeep of this system, the price of parking passes could increase. This could displease many students and faculty and cause more financial anxiety for those who are financially less fortunate.

IV. Resources and Requirements for Implementation

A. Resources

Implement and testing this system it will require the use of different hardware and software components, as listed below under Hardware and Software:

- Hardware
  - Sensors that can detect the presence of vehicles
  - Power supply to power the sensors used to detect vehicles
  - Computer to test the system application to verify it functions correctly and also to code the system
  - A Wi-Fi module will be necessary to transmit the information from the sensors and the signs to the mobile application to show the number of available parking spots to those using the application if wires are not used for connections.
  - Electronic hardware will be necessary to control the power subsystems to determine whether backup power is needed and if it is not needed, then the backup power needs to be charging until it is needed again.
- Software
  - Programming software to use to program the sensors
  - Programming software that can control the application and receive information from the database

B. Personnel and Skills

Due to the extent of this project, it will be necessary to have two teams to continue this project from the last group: an Electrical and Computer Engineering team that will lead the project and continue the work of the last Electrical and Computer Engineering team and a Computer Science team that will implement an AI system into the project.

1) *Electrical and Computer Engineering Team:* The Electrical and Computer Engineering (ECE) team will be responsible for leading the two teams mentioned and maintaining the previous work of the last ECE team to work on this project. The group members of the ECE team bring a range of specialties from the fields of ECE. The team members of the ECE team are mentioned below, along with their respective skills and experiences they bring to this project.
   - Brady Beecham
     - Programming Languages: C/C#/C++, Python, VHDL
     - Software Skills: Object-Oriented Programming
     - Hard Skills: Soldering, Knowledge of electronic test equipment such as multi-meters, oscilloscopes, etc.
     - Engineering Experience: Co-op involving embedded software development
   - Kyle Plant
     - Programming Languages: Assembly, C/C++, VHDL, MATLAB, R, SQL, LISP, Bash, currently in the process of learning Python
     - Software Skills: Microsoft Word, Microsoft Excel, AutoCAD, LTSpice, Git, Unix, Docker, SaltStack
     - Hard Skills: Soldering, Arduino, Raspberry Pi, Electronics repair and troubleshooting, Reading controls schematics, Electrical circuit wiring.
     - Engineering Experience:
       * Internship at a chemical company involving database querying, statistical analysis of PLC data about gas purity and composition, GUI design.
       * Internship at a chemical company IT department involving network administration, troubleshooting, hardware installation and setup.
       * Internship at an automation and system integration company as a Controls intern that involved making AutoCAD controls schematics for motor panels, conveyor device layouts, and I/O modules.
   - Michael Sisk
     - Programming Languages: C/C++, Assembly, MATLAB, R, Currently learning PLC Ladder Logic for Allen Bradley PLCs
     - Software Skills: Microsoft Office, Google Drive, LTSpice, Microsoft Visual Studio, Currently learning Rockwell Automation Software Studio5000 and Rockwell Automation FactoryTalk Software for Allen Bradley PLCs
     - Hard Skills: Soldering, Electronics repair and troubleshooting, Reading electrical schematics, Electrical circuit wiring.
     - Engineering Experience: Internship at a beverage company involving updating safety procedures for the company's bottling facility. Obtained hands-on experience installing and repairing electrical equipment such as electrical switches, induction motors, etc. and troubleshooting electrical equipment in the bottling facility under the supervision of the facility's electricians.
   - Khalifah Altamimi
     - Programming Languages: C++, Assembly, MATLAB, R, Currently learning PLC Ladder Logic for Allen Bradley PLCs
     - Software Skills: LTSpice, Visual Studio, Microsoft Office, Currently learning Rockwell Automation Software Studio5000 and Rockwell Automation FactoryTalk Software for Allen Bradley PLCs
     - Hard Skills: Electronics repair and troubleshooting, Soldering, Reading controls schematics, Electrical circuit wiring
     - Engineering Experience: Tutor and Grader for the Electrical and Computer Engineering Department at Tennessee Technological University
   - Abdulrahman Alrudayan
     - Programming Languages: C++, MATLAB, R, Currently learning PLC Ladder Logic for Allen Bradley PLCs

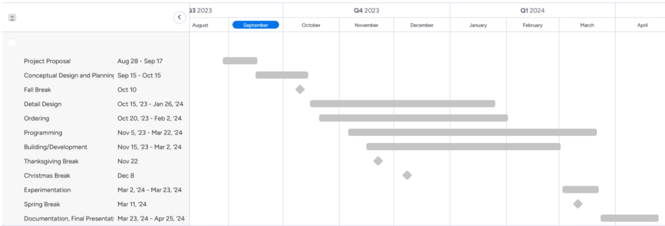

Fig. 1. Expected Timeline

- Software Skills: LTSpice, Visual Studio, Microsoft Office.
- Hard Skills: Electronics repair and troubleshooting, Soldering, Reading controls schematics, Electrical circuit wiring

2) *Partnerships*: Our team will also being working together with a team from the Department of Computer Science. This team will focus in implementing artificial intelligence (AI) to the application software for future use and development of the system. Due to the background and knowledge of the ECE team members, the collaboration between the Department of Computer Science is instrumental in the continuous development of the system to help students find available parking in an efficient and timely manner.

C. Budget

The cost of each parking lot will vary depending on the number of entrances and exits in a specific parking lot due to the ground-based approach this project takes. The single parking lot can have multiple entrances/exits. Therefore, each entrance and exit must be monitored individually for vehicles entering and exiting the parking lot. Since the parking lots are not one direction entrance or exit, each entrance to the parking lots is considered as an entrance and exit. Therefore, the operational budget will be in the range of $300 - $700 for each parking lot with 2 or 3 entrances and exits.

D. Timeline

The group expects this project will be complete in nine months. Figure 1 shows the projected plan of progress for the project. At the beginning, general ideas for the system will be considered. As the project progresses, the group will create detailed designs of the system at the halfway point of the time frame and end the project with experimentation and a product capable of helping people to find available parking in an efficient and timely manner. These deadlines are the class deadlines, so this timeline may cause possible issues with the ordering of parts if specific parts that are required for the system to function properly are on the backlog with the manufacturer.

V. Conclusion

Students at Tennessee Tech University, especially commuter students, deal with a recurring parking issue that seriously interferes with their everyday routines and educational plans. The lack of parking places in some campus regions creates this problem since it forces students to save time looking for spots, frequently in locations other than where they need to be. Students become frustrated as a result, which leads to delays. Technology that offers real-time data on parking spot availability around campus could be a game-changing solution to this issue. A system like this would make finding parking less stressful and time-consuming, decreasing the likelihood of students being late for class and other campus activities. A ground-based parking lot surveillance system is one viable solution to this problem. This cutting-edge technology offers more mobility than traditional camera-based systems, which may have coverage restrictions, particularly in locations lacking surrounding structures for camera placement. It is a practical and effective solution since users may receive the most recent information on parking availability by strategically placing ground-based sensors in parking lots with clearly marked entrances and exits. Tennessee Tech University's reported parking congestion issue emphasizes the need for a solution that improves the parking experience for the entire campus community. This project aims to create a proof-of-concept for a vehicle counting system that can precisely count the number of parking spots available lots without relying on cameras. Students, staff, and visitors to the school may experience fewer parking difficulties if a ground-based parking lot monitoring system is implemented, ensuring that they can locate available parking in a fair length of time. This initiative aims to increase public awareness of the advantages of utilizing technology to better campus life and the parking experience.

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