High Level Design

Park of the Covenant

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1 Introduction

Finding space in a parking garage can be both time consuming and frustrating. It's easy to spend several minutes driving through parking garages looking for an open space. This wastes both time and gas. While time may seem trivial, both the parking garage owners and users lose money because of this problem. The total gas usage during this time for all drivers is very high. A "smart" parking garage would offer a solution to these problems. This sort of solution does already exist in a very small number of parking lots or parking garages.1 However, we believe that we can offer a high quality parking facility solution that is much more affordable than what is currently available.

2 Problem Statement and Proposed Solution

Our solution is to create a smart parking garage that includes multiple ways to present information to a user. Our users will be drivers who need information about where the open parking spaces are located so that they can quickly navigate to those spaces. We will need a way to sense where there are open spots and then display that information to the driver. Determining whether every single parking space is occupied or vacant is not necessarily needed. Directing cars to a particular zone of spaces in a garage will be sufficient in many cases, and this allows for a great reduction in system costs.

In implementing this solution, we will pursue two approaches. The first approach will consist of IR sensing. An IR Vertical Cavity Surface Emitting Laser (VCSEL) will be placed at one side of an entrance to a zone in the parking garage. On the opposing side of the entrance, an NPN Silicon Phototransistor will be placed to receive the signal from the laser. 2 pairs of these devices will be used at each entrance to determine whether a vehicle is entering or exiting a zone. When the laser beam is interrupted by a vehicle, the phototransistor circuits will output a signal. This signal will be transmitted by a wireless network to the microcontroller. The microcontroller will then track the number of occupied parking spaces in each monitored zone.

A second approach to sensing will consist of mounted cameras at entrances and a central computer that will perform video processing to track vehicle movements. Regardless of which sensing approach is used, our software program will continually monitor the state of the parking garage zones. Drivers will be notified of zones with open parking spaces by a display at the front of the parking garage. This display will show a map of the parking garage and highlight the zones with open spaces. We also plan to create a smartphone application which could show the driver where the open spaces are located. This would entail uploading the data from the microcontroller to an online service where user can access the data via a smartphone application. The application would show drivers exactly where the open spaces are in relation to themselves and would not need to waste time searching for an unoccupied spot.

3 System Requirements

3.1 System Intelligence

3.1.1 Video Processing

For video processing, the system has to be able to receive a video of everything passing in front of the camera, determine whether the passing object is a motor vehicle or non-motor vehicle, using edge detection and object size analysis video processing functions. If the object passing is determined to be a motor vehicle, then the video processing system needs to determine the direction in which the motor vehicle is moving. Using this information the system can be integrated to determine total traffic in and out of a traffic zone.

3.1.2 Infrared Sensors

For the IR system, the device will involve a pair of IR sensors in sequence. Each IR sensor will need to be able to determine whether its beam is being interrupted or not, and send information to the processor accordingly. The system will need to be able to determine the direction in which the vehicle is moving, by sensing which of the two sensors is tripped first. The system will need to be able to communicate with other pairs of sensors to determine traffic in and out of a traffic zone.

3.2 System Power

Both of these devices will be powered via a wired connection and a power converter. This is possible because of the wiring usually present in a parking structure-type location, it is fairly easy to make wiring connections for the powering of such a system. Either application would have to include a power converter, which would be dependent on the nature of the power supply of the garage, but would probably end up being some sort of Buck converter stepping an AC voltage source down to the DC needed by the system.

3.3 User Interfaces

The information that the system is compiling will be displayed to users on a screen at the entrance to the parking garage, which will allow parking users to determine areas where they would be most likely to locate an available spot. This screen has to be easily readable to users in their cars and must be configured in such a way as to be easily understood with relative ease, requiring minimal reading time, so as to minimize congestion due to people reading the screen.

3.4 Usage and installation

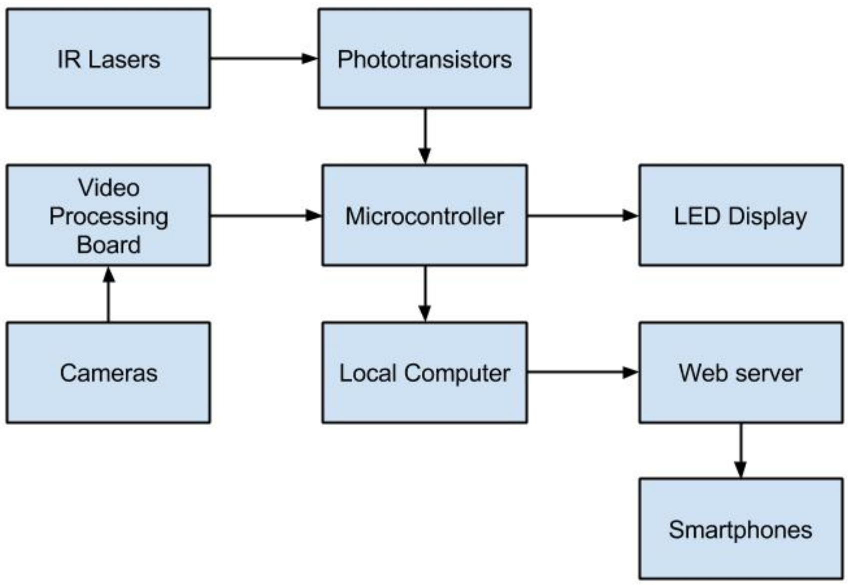
Video input sources will be placed at entrances and exits to “zones” or parking garages where traffic passes through. A zone is defined as any area with a limited number of ways in which to enter/exit, so as to be easily monitored. These devices will network with a central processor which analyzes data and outputs to the display system(s). Installation of a system will be somewhat different for each garage, as increased granularity will be provided by cutting the area in to more zones. Wired video input modules will have to be placed in an area where they could monitor the choke points for each zone, at a range where the camera can properly view passing vehicles.

3.5 Safety Considerations

Our device does not operate at voltages or currents that are considered dangerous to human users, but there are safety concerns inherent in the installation of the system into the wiring system of the parking garage, as that voltage or current could possibly be considered dangerous to humans, so caution should be exercised in the installation of our system. For demonstration purposes, we will probably seek to power the system from a wall socket or some mobile power source, such as a car’s AC outlet, so as to avoid tasks that would normally require a licensed electrician. Other safety concerns involve the distraction of drivers in the garage, the system cannot pose as a significant distraction to drivers. To avoid this, the information display will be placed in a location where drivers will have to be stopped in order to see it, at a location such as an entry gate or other speed-inhibiting choke point. This will prevent any traffic incidents due to driver distraction caused by our system. The system sensors will also be placed in locations that are inconspicuous and will not have to be avoided by drivers, and will not cause any sort of noises or output any light signal which could be distracting to drivers passing the system sensors.

4 System Block Diagram

4.1 Overall System:



4.2 Subsystem and Interface Requirements:

4.2.1 Infrared Sensor Subsystem Requirements

The IR Sensor Subsystem requires an infrared laser circuit, externally powered by a battery supply. This circuit is standalone and interfaces with the rest of the block through the laser alone. Interfacing with this laser is a photodarlington sensor circuit—the sensor itself is shielded from external light and interfaces directly with our microprocessor. The sensor outputs a constant VDD when struck by the IR laser, but when interrupted by an object it outputs a value close to GND. This signal is interpreted by input pins on the microcontroller, which lights an LED when the laser and sensor are properly aligned and, through software, counts the number of objects passing this certain point.

By using two of these subsystems at an entrance or exit of a garage section, we can determine the direction of object motion. By measuring the amount of time each sensor is blocked by an object and using average vehicle speed in a garage, we can roughly calculate the length of an object and determine whether it is a person, which will not be counted, or a car, which will be.

With this vehicle count stored in the microprocessor, now it must get to our display system. For this to occur, we must interface the microprocessor with the display board.

4.2.2 Video Processing Subsystem Requirements

The video processing subsystem will consist of cameras at each section wired to a central processing hub. The cameras will be inexpensive, since the video requirements will not require a high frame rate or high definition resolution. Provided the lighting within the parking garage is sufficient, the camera can also capture video in grayscale, since high color differentiation is not needed to detect the difference between a car and a person. To process the video feed, a separate controller will be required. These are specifically used for video processing. Currently, the video processing is being done on a PC using MATLAB software, to demonstrate that this approach can be a viable form of counting cars. The cameras will send the feed to the video processor through a wired connection, which will then output the necessary data to the microcontroller

4.3 Future Enhancement Requirements

4.3.1 Enhanced Shape Recognition Capability

Allowing for higher precision shape recognition: Being able to distinguish between various varieties of vehicles could provide parking garages with data as to the usage of their facility and could lend to the tracking of specific vehicles through the system. This capability would also increase the system’s ability to distinguish between people and smaller vehicles, like smartcars and motorcycles/ scooters.

4.3.2 Enhanced Granularity of Data

Being able to monitor smaller areas of parking systems would allow for a more detailed view into the garage’s level of occupancy at any given time, and would allow for the system to be better able to guide a customer closer to a specific open spot, rather than indicating an area with an open spot.

4.3.3 Weatherproofing and Increased Ambient Light Resistance

Weatherproofing and increased ambient light resistance: By increasing the system’s tolerance to changes in ambient light and increasing the weatherproof qualities of our modules we could implement our system outside of parking garages and parking garages with uncovered roof parking levels.

4.3.4 Development of Signal Relay/ Boosting Units

By designing signal relays and boosters, a wireless system of cameras can service a larger area and be farther away from the central processing unit.

5 High Level Design Decisions

5.1 Selection of IR components

The IR sensing subsystem will send a signal to the microcontroller each time an object crosses the IR laser beam. Our program will interpret a high signal as an uninterrupted beam and a low signal as an interrupted beam. 2 pairs of a laser and sensor placed at the entrance/exit to a parking zone will enable tracking of the direction of a vehicle and whether it is entering or exiting the zone. Our laser will consist of a Vertical Cavity Surface Emitting Laser (VCSEL) and our sensor will be a phototransistor. More specifically, the phototransistor will be a photo darlington with an opaque lens to provide shielding against stray light. A tube on the order of 1ft. in length will also be placed over the phototransistor to provide additional shielding of stray light. Mounting the VCSEL and phototransistor will likely require the use of visible lasers to help line up the devices.

5.2 Wired vs. Wireless data linkage to central processing unit

Because we intend to use this technology inside garages, we have decided to wire the sensor systems to the microcontroller. Wireless signals will degrade too much, and would become too expensive to use for the amount of sensors that we intend to use. We need to find wire that can small signals over hundreds of feet while also remaining incospicuos to parking lot users.

5.3 Method of outputting data to end user

At the entrance to the parking garage, we intend on setting up an LED display which will show how many parking spots are available in each zone. We also will upload the data to a web server via a computer connection from the board which can then be accessed on smart phones. Users can then see as soon as they get to the parking garage which level has available spots to park in.

5.4 Intended parking facility usage

Because we have decided to use the zone based approach, we think that his system can be better implemented inside a parking garage than instead of outdoor parking lots. We can set up the IR sensors and cameras at the entrance and exit of each level of the parking lots, and then count how many cars enter and exit each level. Another advantage of parking garages is that the IR sensors are more reliable inside rather than outside in a garage. This is because there is less variance and interference from ambient light, which can cause the IR sensors to be unreliable

5.5 Zone based approach vs spot-by-spot monitoring

Originally we wanted to have a sensor in each spot in the parking lot which could tell whether or not the spot was occupied. We decided that the sensors for this approach would be too cost prohibitive, and we decided to use a zone based approach. We will count how many cars pass certain points in both directions in order to calculate the amount of open parking spaces in any zone. This approach will allow for a much lower amount of sensors while still giving the users the ability to see where there are open parking spaces because it only requires sensors at the entrance and exit of any zone rather than in every spot.

6 Open Questions

6.1 Best sensor approach

We are still trying to determine whether or not IR beam sensing or video processing would be the better approach for vehicle detection in our system. Video processing allows for more future utility and increased accuracy, but IR's much lower cost makes it ideal for a very granular approach, although this approach cannot distinguish between cars and non-cars passing through as easily as video processing can.

6.2 Video Output Questions

We still have questions as to how we are going to output the results of our analysis to the end user. We have ideas of using video screens and LED boards, but until we get an idea of the costs inherent in both solutions and the interfaces needed for both methods, we will not have a decision on this matter.

7 Major Component Costs

Budget: $500

Processor (board): $50

Video cameras: $~10ea x 6 cameras ~ $60

IR laser: $5.71ea

Phototransistor (black Photodarlington): $0.34/ea

8 Conclusions

Our system hopes to alleviate some of the headache involved in locating parking spaces in a large and crowded parking lot. By directing people to a specific zone where there are spots open, we can decrease the time that people drive around looking and waiting for parking spots, we can decrease the congestion in parking garages, and increase profitability for these parking structures.

A lot of work still needs to be done, our next steps include choosing our sensor approach, determining an approach for outputting data to customers, and integrating our subsystems together into a functioning product.

Park of the Covenant hopes to take a step forward in revolutionizing parking in garages by creating a system that allows garages to affordably increase the efficiency of their building by alleviating the stressors affecting their parking experience.

References

1. Charette, Robert N. "Smart Parking Systems Make it Easier to Find a Parking Space." 1 Oct. 2007. IEEE Spectrum. 12 Dec. 2013. http://spectrum.ieee.org/green-tech/advanced-cars/smart-parking-systems-make-it-easier-to-find-a-parking-space