PVision Electronics

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February 6, 2012

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Functional Specifications for the PVision Parking Convenience System

Dear Dr. Rawicz,

We are writing with regards to the functional specifications for a Parking Convenience System which we have attached for your ready reference. The objective of our project is to design a system which dynamically monitors the parking spots in a parking lot and informs drivers of the vacant and occupied spots in advance of them entering the site. The project functions on the principles of minimalistic design in order to develop an efficient and robust system which is user centered and financially attractive to our direct clients – owners and administrators of parking lots in malls, universities, hotels and other institutions.

The document provides the detailed functional specifications of our product by breaking it down into its three independent, but connected, components. The overview provides a black-box representation of our and is followed by the specifications which range from electrical and mechanical to durability and environmental requirements.

PVision is composed of five engineering students in the final year of their undergraduate degrees. The executive team consists of Mohammad Akhlaghi, Oshi Mathur, Milad Haji Hassan, Noah Park and YuJie Xu. We would be delighted to hear from you in case you would like to further discuss our proposal.

On behalf of the executive team,
Sincerely,

M. Akhlaghi

Mohammad Akhlagi
Chief Executive Officer (CEO)
PVision Electronics Limited

Enclosed: Proposal for a Parking Convenience System

Functional Specification
Parking Convenience System

PVision Electronics

Project Team:

Mohammad Akhlaghi - CEO
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Submitted to:

Andrew Rawicz (ENSC 440)
Steve Whitmore (ENSC 305)
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Issued date:

February 6, 2012
Revision 1.7

Executive Summary

Stephen just got off the phone with the receptionist at TransCan Electronics t confirm the location of their main office. He will be heading out soon for an interview there and wants to make sure he gets there with at least 15 minutes to spare. He checks the time and drives out. Once in the vicinity, he goes to the parking lot closest to the busy mall in which the office is located. He cruises around for a good 10 minutes without any luck. He check his watch to see that he now only has a few minutes before he gets there. All spots seem to be taken on the current floor and in a panic, Stephen scours the net floor for a spot. With only minutes to go before his interview, he takes a chance and parks in a reserved spot. He knows he might have to pay a hefty fine, but he has no other option.

Stephen's story is all too common. In busy parking spaces all around the world, precious time and fuel are wasted in finding parking spots. This problem occurs on a global scale yet little has been done to solve it. Existing solutions rely on expensive renovations using costly sensors which require regular upkeep.

An exploration into this issue conducted by the Department of Urban planning at the University of California suggests that people in the major cities in North America spend about 8.1 minutes finding a parking spot in the city's core during work-hours. As per the report, such vehicles constitute over 30% of the traffic cruising in any given area.

To add to the gravity of the issue, one is forced to consider the carbon emissions associated with idling cars in a situation like Alex's – waiting for a car to vacate a parking spot, circling around the block for free spots and so on. A survey conducted by ParkingAuction.com, a website dedicated to solving parking congestion, states that "…on a 15-block section of Manhattan's Upper West Side, the non-profit Transportation Alternatives discovered that drivers burned an extra 366,000 miles hunting for parking in a year. Statistics are even worse in Los Angeles, where 950,000 excess miles were driven per year by parking spot seekers. It goes without saying that those miles add to drivers' carbon footprints. That extra 950,000 miles wasted 47,000 gallons of gas and spewed out an additional 730 tons of carbon dioxide. If all this is happening in small pockets of our major cities, imagine the cumulative effect of all cruising in the United States."

Needless to say, other alternatives have been explored to solve this problem. They all invariably include the use of individual sensors installed in at each parking spot feeding into expensive sytems that monitor the traffic in these spots. Our alternative solution at PVision Electronics is exceedingly low-cost, more robust and allows for a more visual and user centered experience while parking.

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List of Figures & Tables

Glossary

The following notations will be used throughout this document in order to improve the readability.

[**Rn-P**] A functional Requirement
Where **n** stands for the requirement number, and **P** stands for the priority level of the requirement.
The priority levels are assigned as following by one of three values:

I. High Priority Level
II. Moderate Priority Level
III. Low Priority Level

Introduction

Cars are the most common mode of transportation in most countries around the world. Most drivers in the world experience the trouble of cruising for a parking spot in crowded parking lots in malls, offices, and universities - you name it! The drivers have no visual sense of the empty parking spots and their location from the outside. The parking operators are not equipped or obligated to let incoming drivers know of the empty parking spots and where they are located. Therefore, the only way for a driver to looking for a vacant spot to park is for him or her to drive through the entire parking lot to cruise for an available parking spot. If the space of parking lot is huge and multi-levelled, it is very time-consuming. Thus, if the driver is running out of time and looking for a vacant parking spot in a huge parking lot it can be a very frustrating ordeal.

The main goal of our project is to design a system, which dynamically monitors the availability of parking spots in a parking lot and notifies drivers of the vacant and occupied spots before they enter the parking lot. The system uses 2 cameras which are installed in a high view of a parking lot, to capture pictures of the entire lot every several seconds and then analyzes the pictures captured using the image processing algorithm we are going to develop. After that, the analyzed result is sent to the display unit located at the entrance of the parking lot in order to represent a real time map of the parking lot. Thus, before the driver enters into the parking lot, he or she can make an accurate decision on where to park.

This functional specification document details the requirements and the specifics of the components of our system in a three tiered system – the input, the embedded system and the output. The system testing statistics and methodology has also been outlined. Please find a detailed list of all references attached well.

The PVision smart parking system is a device that can be used to efficiently assist drivers in finding free parking spaces in a parking lot without entering it. The system can be installed and removed in any parking lot without any damage to the existing facilities. It consists of three units that are integrated together to create a parking guidance system that detects available/unavailable parking spaces. The three units are as follows:

1. Input Module
2. Embedded Module
3. Output Module

The block diagram of system representing the connection of these three units is shown in Figure 1.

Input Module

The input module consists of the video capture module. It is made of a High Definition (HD) camera which is used to capture video from a parking lot. The input module uses one camera to capture video from the parking lot. However, when a camera is not sufficient to capture all parking space in the designated parking lot, the PVision team will install additional cameras to cover the extra blind spots. This module provides the processing unit the real time image of the parking lot.

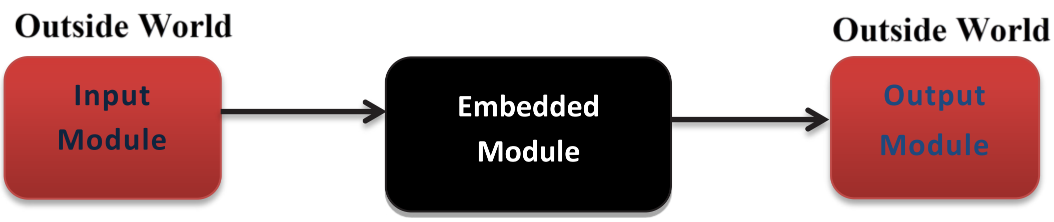

Figure 1: Block Diagram of System

The video to image conversion module is responsible for converting the video to image at rate of approximately five samples per second. The generated images are then sent to the Embedded module to perform the vehicle detection procedure.

Embedded Module

The embedded module is the brain of the system as it uses the images provided by the input module to analyze images and detect the location of vehicles. The result from embedded module is then sent to the output module. The processing module consists of three functions including color detection function, edge detection function, and verification function as they are shown in Figure 2.

The color detection function detects the occupied and unoccupied parking spaces by comparing color of pixels. This function takes the RGB value of specified parking spaces and compares them with the average color of sample points collected from roadway of parking lot. The occupied parking spaces have a different RGB value than the collected sample ground RGB value since the ground is no longer visible from the angle of the camera. In order to improve accuracy, standard deviation and block size RGB collection algorithms are implemented.

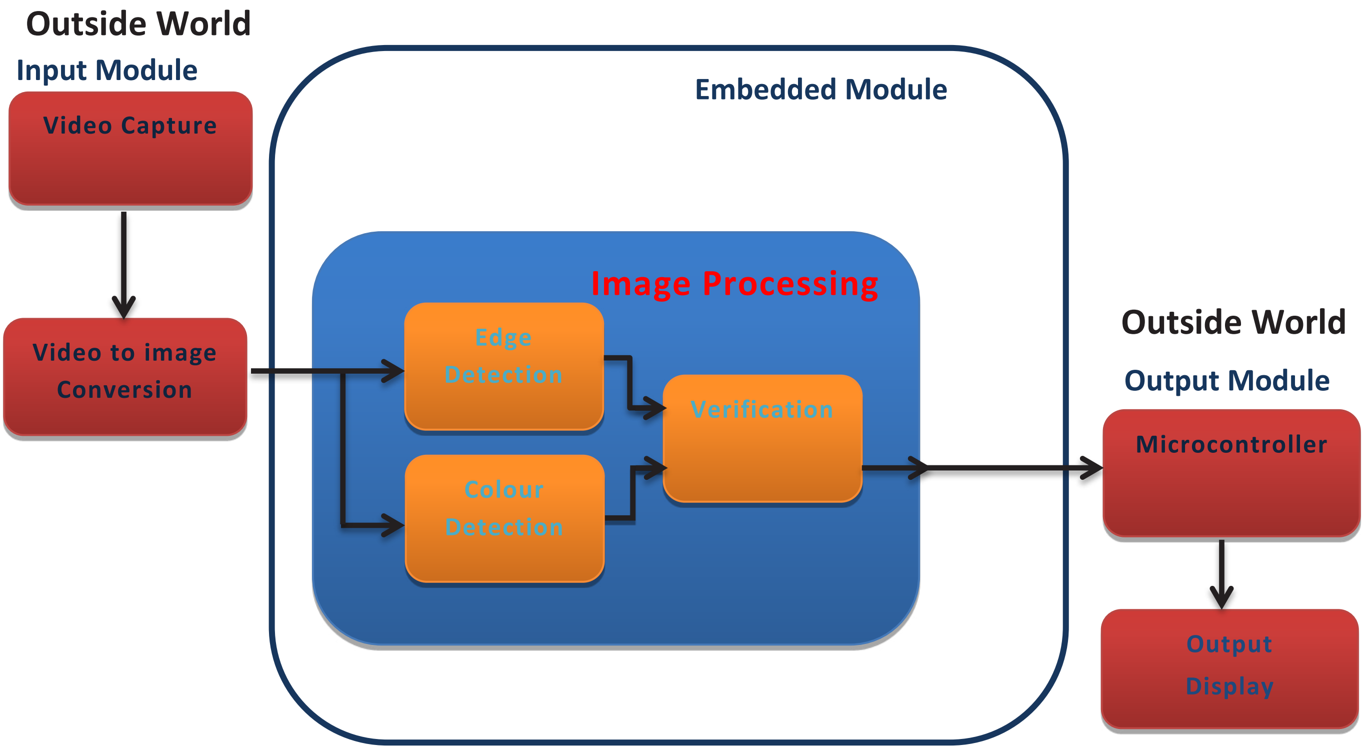

Figure 2: System Overview

The edge detection function detects the edges of vehicle and finds location of cars. The location of cars at each instant of time is then compared to the location of parking spaces using the layout of parking.
The verification function confirms whether the results of the two detection methods agree or not. The verification is done by comparing the results of both methods and checking whether they agree in an acceptable range.

Output Module

The output module consists of the microcontroller and the output screen display. The microcontroller converts the received data from the verification function to readable datas for the output display.

The output screen display is responsible for receiving the data from the processing unit and displaying them on the screen.

User system overview

The user interface of PVision smart parking system is shown in Figure 3. The driver looks at the screen display and finds the locations of empty parking spaces before entering the parking lot. Then, the driver can drive to another parking lot if there is no parking space available for parking.

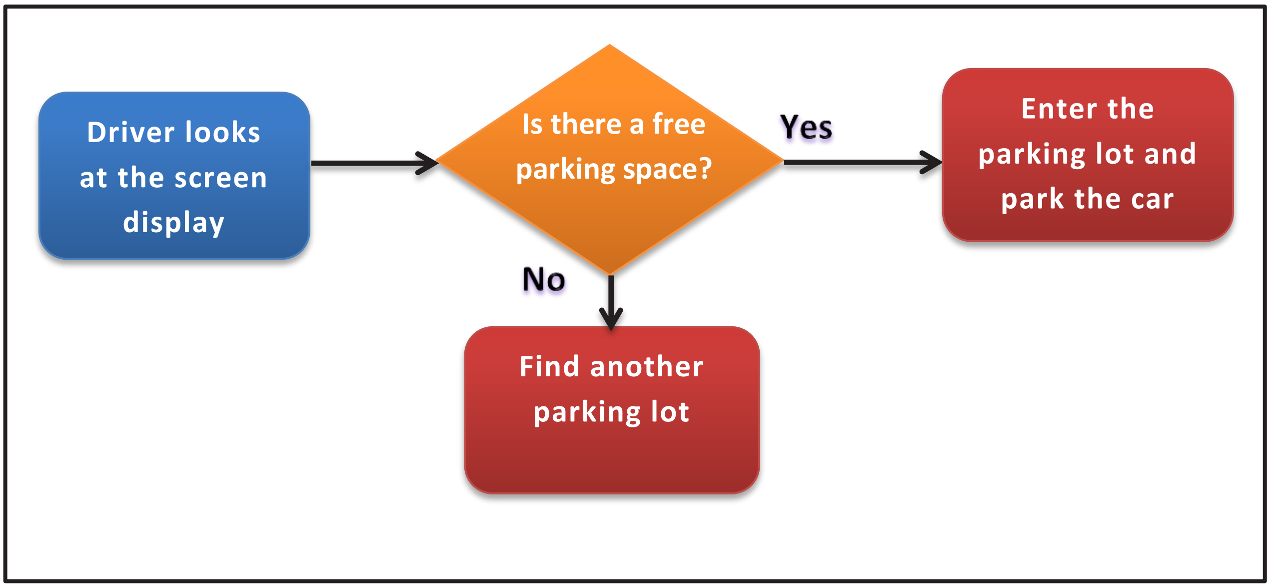

Figure 3: User System Overview

Input module consists of a high resolution (HD) camera which captures continuous shots from the parking lot and provides the images to the embedded software for the further analysis.

Electrical requirements

[R1-I] For small scale prototype the camera must have a serial output (preferably USB) port so that data can be captured easily by using C++ code.
[R2-I] For large scale model the camera will be an IP camera so we will be able to send and receive image data via a computer network and the Internet.
[R3-II] USB camera will power up through the computer but the IP camera will be connected to an 110V power supply or will use the Power over Ethernet(PoE) technology. [5]

Costs

[R4-I] Standard High Definition (HD) web-camera made by Microsoft is $40 CND.
[R5-II] IP camera with night vision function will cost around $400 CND.

Mechanical Specifications

[R6-III] The camera for our first prototype will have a locking mechanism which will hold the camera fixed.
[R7-II] The camera must be able to move around the prototype to do different levels of testings.
[R8- II] For the large scale prototype the camera must be out of reach so it would not get damaged or stolen easily.

Durability and Reliability

[R9-II] The camera must provide high resolution images with minimum noise so the embedded module has greater accuracy in determining the occupancy of the parking spot.

Environmental Requirements

[R10-II] The web-camera shall operate in room conditions.
[R11-III] The IP camera must be water-proof and operate in a range from -40 to 50 degrees.

Packaging

[R12-I] The first prototype will be tested indoors only and does not require special packaging
[R13-II] The large scale must be covered so that bad weather condition does not affect the camera functionality

Response Times

[R14-II] High definition images shall be captured from cameras continuously within 5 second intervals.
Compatibility with Other Systems
[R15-II] The camera should be able to connect through different settings including hyper terminal, IP, Wi-Fi, and Ethernet port.

Known System Limitations

[**R16-III**] Slight movement in camera might cause misleading information.
[**R17-III**] Still image resolution of web-camera can be noisy and not good enough for image processing.

1.Electrical requirements

[R18-1] The power supply for the embedded unit shall be 110 V.
[R19-1] Input current for embedded unit ranges from1.5 A to 1.7 A.

2.Costs

[R20-I] Standard embedded unit (laptop) with i3-2330M, 4G DDR, 500GB HDD, with Windows7 operating system from Dell cost $499 CND. [1]
[R21-II] The licensing cost for Microsoft Visual studio premium is $ 799 CND. [2]

3.Mechanical specifications

[R22- III] The unit size for the laptop is 32.50m*350.00mm*351.00mm. [1]
[R23- III] The unit weight is about 2.55kg. [1]
[R24- II] The unit shall have larger than 10" LCD display to deliver GUI to parking lot managers.

4.Durability and Reliability

[R25-II] The embedded unit needs to provide stable compiling environment while running the Visual Studio software.

5.Environmental Requirements

[R26-III] The unit shall operate within performance tolerances for a temperature range of 0°C to 50°C. [1]
[R27-II] The Microsoft Visual studio shall be installed on computer with following software requirements: Windows XP (x86) with Service Pack 3, Windows Vista (x86 & x64) with Service Pack 2 or Windows 7 (x86 & x64). [3]
[R28-II] The embedded unit has following hardware requirements: a 1.6GHz or faster processor, 1 GB (32 Bit) or 2 GB (64 Bit) RAM, 3GB of available hard disk space, 5400 RPM hard disk drive, and DirectX 9 capable video card running at 1024 x 768 or higher-resolution display. [3]

6.Packaging

[R29-III] The unit shall be installed indoor only. Thus does not require extra packaging for protection.

7.Standards

[R30-I] The embedded unit shall support Windows 7 operating system.
[R31-I] The embedded unit shall be compatible with Microsoft Visual studio 2010.

8. Response Times

[R32-II] The embedded unit shall provide enough processing power to complete a single frame of image within 3±1 seconds. Processing time over 5 seconds could result in skipping a cycle of image processing.

9. Compatibility with Other Systems

[R33-II] The embedded unit shall use USB or Ethernet cable to upload the input stream of images from the camera and save them into a specified folder.
[R34-II] The embedded unit shall send output signal to the video through hyper terminal.

10. Known System Limitations

[R35-III] As the demands for CPU processing power is great for each frame of image, Microsoft Visual Studio shall be given 5 seconds processing time, required to complete one cycle of image processing.

1. Durabili,ty and Reliability

[R36-II] The algorithm shall handle unexpected or corrupted input data from the camera without crashing the system.
[R37-II] Vehicle detection algorithm shall not recognize person or other objects as a vehicle
[R38-II] Algorithm shall also detect vehicles that have not been properly parked right in the middle of the parking space.
[R39-II] Algorithm shall also detect vehicles in any color.

2. User Interface Requirements

[R40-III] The algorithm shall provide GUI which consists of three main modes.
[R41-II] The algorithm shall display real time-images of the parking lot that refreshes every 5 seconds.
[R42-III] The algorithm shall display overall statistics of the parking lot including #of total spaces, #of available spaces, and the graph of parking lot occupancy level over time, and expected rate for the vehicle at each designated parking space.
[R43-III] The algorithm shall provide coordinate configuration tool and instructions for the parking lot manager.

3. Environmental Requirements

[R44-III] The unit shall handle unexpected or corrupted input data from the camera without crashing the system.
[R45-I] Vehicle detection algorithm shall detect vehicles in any weather conditions.
[R46-I] Given that visibility is secured from the camera location, algorithm shall successfully detect vehicle in the parking space.

4. Standards

[R47-I] The source code must be compatible with Visual Studio 2010 and C++ library.

5. Response Times

[R48-II] The algorithm shall complete one cycle of image processing within 3±1second.

6. Compatibility with Other Systems

[R49-I] Source code shall process image formats such as JPG and BMP.

7. Known System Limitations

[R50-III] Algorithm cannot detect vehicles when visibility is not secured by the camera.
[R51-III] Algorithm cannot accurately detect vehicles at night time if lighting is poor.
[R52-III] Algorithm cannot process images that have been altered due to the changes in the camera angle or position.
[R53-III] Algorithm cannot detect motorcycles that do not occupy 1/3 ground area of parking space.

Output Module

The output module consists of a Graphics Processing Unit (GPU) which relays the data in receives from the embedded system and displays a schematic of the parking lot which informs the user about the location of vacant and in-use parking spots in a visual manner. The use of the GPU is set for the first prototype of PVision, however, the final production system may use a different output system. As such, most functional requirements for the output system have been deemed as proof-of-concept requirements only.

Electrical requirements

[R54-I] The GPU will function in a 2.7 V – 3.4 V environment with a maximum forward voltage of 3.2 V.
[R55-I] The typical Power supply current will be 50 mA with a cap at 60 mA. Accordingly, the maximum forward current will be 60 mA.
[R56-I] The maximum power dissipated by the GUP will be 192 mW.

Costs

[R57-I] The GUP, bought from VIZIC Technolohies, costs $ 85.00 (USD)
[R58-III] Larger outdoor LCD screen will cost upwards of ~ $10,000.

Mechanical specifications

[R59-I] The active area for the LCD screen is 36.72 mm * 48.96 mm in width and length respectively. The outline dimensions with encasing are 42.32 mm * 59.03 mm in iwdth and length respectively.
[R60-II] The screen is capable of function in landscape or portrait orientations.
[R61-II] The GPU can be mounted in any orientation and can be hand-held for demonstration making use of the touch-screen capabilities.

Durability and Reliability

[R62-I] The GPU can be operated ideally in a 25 degree Celsius environment.

[R63-III] The LCD screen for the final production must be in an encasing made of materials such as plexi-glass for functioning in outdoor parking lots.

Environmental Requirements

[R64-I] The GPU can be operated ideally in a 25 degree Celsius environment.
[R65-III] The LCD screen for the final production must be in an encasing made of materials such as plexi-glass for functioning in outdoor parking lots. The operating temperatures must also be in a large range for summer and winter temperatures.

Packaging

[R66-I] The first prototype will be tested indoors. It will not be packaged.
[R67-III] The final production unit will see the LCD screen and the embedded system merge and will be packaged to allow for optimal operating conditions in outdoor parking lots.
Compatibility with Other Systems

Compatibility with Other Systems

[**R68-I**] Easy 5 pin interface to any host device: VCC, TX, RX, GND, RESET
Known System Limitations
[**R69-I**] Temperatures outside 25 ^{0}C ± 5 0C can see a non-responsive system
[**R70-III**] Humidity should remain under 65% RH.

1. Unit Test

The parking guidance system consists of three main modules: camera, embedded unit, and microcontroller/display. In order to shorten the time it takes to eliminate potential errors caused by each module, module testing will be conducted prior to the integrated system testing. Electrical, physical, sustainability, response time, safety, usability and environmental requirements will be thoroughly tested before and after the integration.

Camera(s)

The camera is expected to be installed outdoors as it needs to provide real time video information of parking lot to the embedded unit. Therefore, the test plan for the camera needs to ensure that it is in operation even in extreme weather conditions. The camera needs to be resistant to changes in humidity and temperature. Outdoor testing will be conducted where the camera will be exposed to rain and wind for a few days. During outdoor testing, it will be important that particles in the air or precipitation do not block the lens, causing noise and blurr. Electrical components of camera shall be protected against water during outdoor testing.

Embedded Module

Unlike the camera and the display, the embedded module will be implemented indoors using a regular performance laptop; the environmental effects will be minimal. However, the test plan for the embedded unit will consist of stability tests for C++ source code. Various input images (including corrupted image files) will be fed to the compiler. The C++ source code will also process the stream of input image files over a long period of time. Before the integration of the system, the source code will be continuously run for hours while closely monitoring memory overflow and compliers. Image processing for a single frame of video will need to be completed before the next frame is loaded and processed. Processing time will be measured for different quality of image files and system environment.

Microcontroller/display

Microcontroller and display need to make sure that input from the embedded module can be displayed in a timely and error-free manner. Visibility tests will be required for the items on-screen. If the size and the color contrast of vehicle occupancy indications on screen are not clearly visible to the drivers in the vehicle, drivers will not leverage the convenience of our parking guidance system. Corrupted input from embedded system will be fed to the microcontroller to test whether it can handle such unexpected events or not. Packaging needs to be tested in order to make sure that the screen inside the package is well protected from weather and theft.

2. Integration Test / Simulation

Once every module satisfies all of the requirements, integration tests will be conducted on the fully integrated system. Integration tests will focus on interoperability between embedded unit and the rest of the modules. The ideal positioning of camera location, brightness/contrast setting, and noise reduction filters need to be configured and tested upon integration of camera and the embedded unit. Using trial and error method, the Pvision team will find the optimizing configuration settings to ensure the accuracy from the given images from the camera. Different lighting conditions can also affect the output results. Therefore, it is important that repeated tests are conducted at a different time of the day. To ensure flawless vehicle detection in different weather conditions, testing will be carried out on clear, cloudy, and rainy days with varying precipitation.

The system is likely to be installed around parking lot with more than 2 cameras placed on opposite side of the parking lot. As the distance between the cameras and the embedded unit is expected to be over 30m, longer length cables need to be used to support communication among modules. Tests will be conducted to ensure that the transmission loss between the modules do not affect the image processing and the output result.

The Pvision team has been searching for test sites. On campus parking lots such as Lot-B, C, D, E, F, library 1st and 2nd floor, west mall and other visitor's parking lot have been reviewed for their conditions. Before determining the test site, our team will contact parking manager for availability and further assistance for the future tests. Testing in the parking lot with cameras might cause privacy issues and public concerns. It is crucial that Pvision team inform Parking / Security and closely coordinate with them to eliminate such concerns.

User Interface

Two types of user interface will be implemented for the system: system interface for end users (drivers) and parking lot managers. End-user display shall be installed near the entrance of the parking lot.
Use interface for end user (driver) follows 3 main categories.

1. Entrance Display

Large LCD screen installed at the entrance of the parking lot will display the parking availability. This display will get updated every 5 seconds to show the most accurate results.

2. Mobile application

Drivers will be able to check the availability of parking lots close to their current location using their mobile devices. Using this technology driver will have the option to choose between parking lots with the most available spaces to save time and gas.

User interface for parking manager supports three main functions.

1. Webcam Current parking lot (Ideal mode)

When the system is in ideal mode, the screen will display the view of the parking lot. The display will be refreshed with the latest picture of the parking lot every 5 seconds.

2. Statistics & Rates

When the user click on an item called statistics and rates, user interface will provide the overall statistics for the parking lot including the number of total spaces, the number of available spaces, graph of parking lot occupancy level over time, and expected rate for vehicle at each designated parking space. Above information will help them manage their parking lot more efficiently.

3. Coordinate configurations (Initial settings)

When the parking manager installs the system for first time, he/she needs to manually configure the coordinates for each parking space. This will be done by simply clicking on points on the image of the parking lot. User interface will provide instructions to help and guide managers to finish configuration steps as efficiently as possible.

A website for the system will be developed which will contain the following information:

1-User manual on how to install and maintain the system.
2-Information about the warranty of our system.
3-Link to the 24/7 customer service and sales representatives.
4-Video instructions for parking owners on how to effectively manage their parking lots using our system.
5-Video Instruction on how the system works and the benefits of it for the end user.

Since our target market is North America, the website will mainly be in English language.

Conclusion

The parking convenience system, as a first prototype, can be viewed as a three-tiered system consisting of a sensory input in the form of cameras, an embedded system which contains the algorithms which take the image data and process it to assess the number and location of the vacant and in-use parking spots, and finally, an output system in the form of a GPU which displays this data graphically to the user.

The functional specifications of the prototype allow it to perform in a lab environment which can, with some work, be adapted well to a real-world parking environment soon. Mid-February will see us implement and test the first prototype with a final production model to be developed in March.

References

[1] Dell Inspiron 14R Laptop
<http://www.dell.com/us/p/inspiron-14r-n4110/pd>

[2] Visual Studio 2010 and MSDN Licensing White Paper
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[3] Visual Studio 2010 Premium system requirements
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[4] description of Power over Ethernet
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[5] Smart GPU Vizic Technologies
<http://vizictechnologies.com/#/smart-gpu/4554296549>