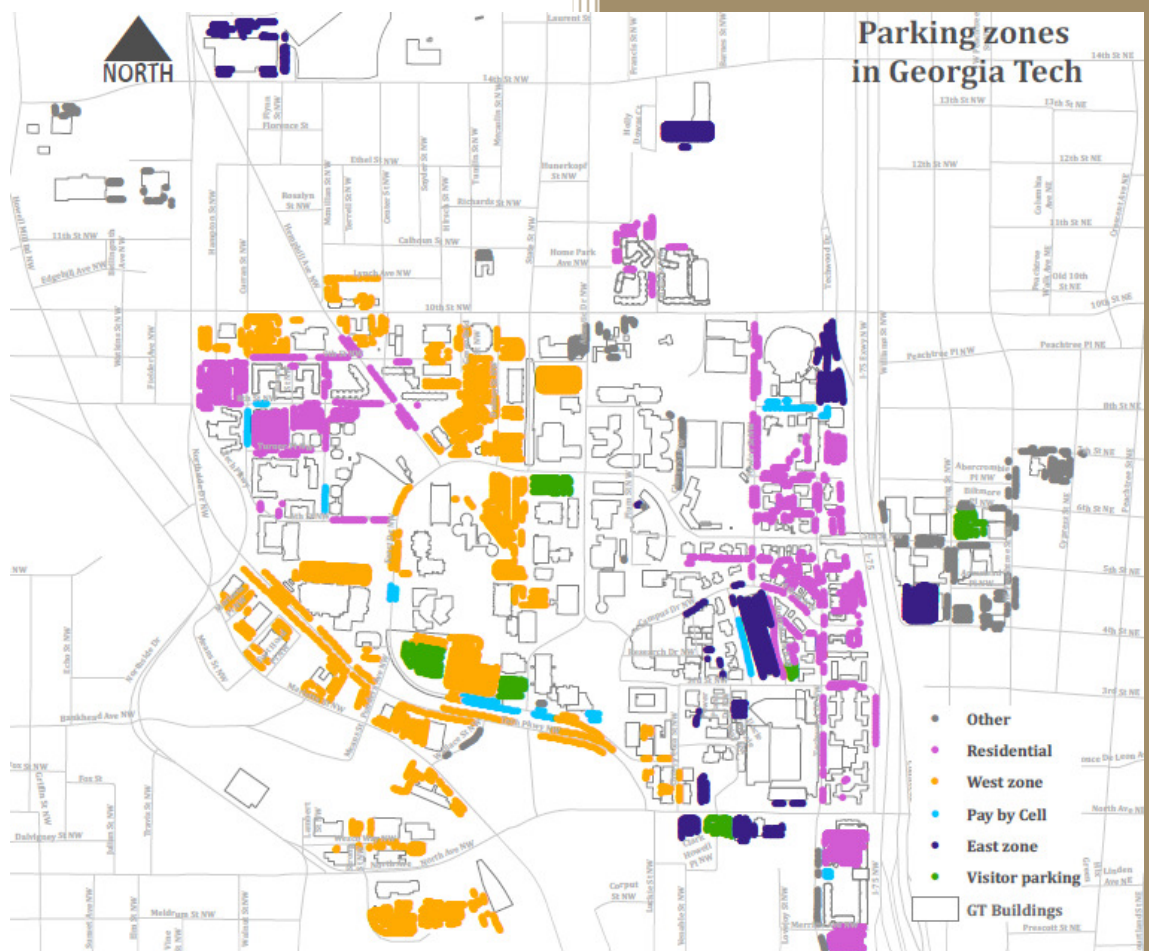


# Parking Management System for Georgia Tech



Nilesh Deshpande  
Adviser: Prof. Subhrajit Guhathakurta  
School of City and Regional Planning  
Georgia Institute of Technology  
April, 2014

## **Acknowledgement**

I would like to thank the following people for their help, guidance and invaluable inputs during the course of this study.

### **Center for GIS, Georgia Institute of Technology**

Prof. Subhrajit Guhathakurta

Ramachandra Sivakumar

### **Parking and Transportation Services**

Ritchie K Brown

Sherry Davidson

Michael Green

Lance Lunsway

Emmaricia Madison

Manisha Mishra

Keith Trawick

Torise Young

Kimala J Whitehead

## Table of Contents

Acknowledgement.....	1
Table of Figures.....	3
Introduction.....	4
Existing technology and research.....	5
Overview .....	5
Vehicle detection and Current Parking occupancy.....	6
Parking forecast and assignment.....	8
Smart phone based applications: .....	11
Existing Parking Infrastructure .....	14
Data collection .....	14
Data Overview.....	16
Existing Real-Time Parking Monitoring Systems .....	22
Proposing a prototype.....	24
Back End.....	24
Parking Assignment.....	24
Front End .....	25
Smart phone application.....	25
Designing a smartphone application .....	26
Conclusions .....	32
References .....	33

## Table of Figures

Figure 1: Phase 1 - Mapping parking spots based on satellite imagery. Map shows the parking spots near Institute of Paper Science and Technology .....	15
Figure 2: Phase 2 - Mapping parking spots using floor plans. Map shows parking spots at the parking garage at North Avenue Apartments.....	16
Figure 3: Handicap parking spaces in Georgia Tech’s campus.....	18
Figure 4: Verified parking spaces in Georgia Tech’s campus.....	19
Figure 5: Parking zones in Georgia Tech .....	20
Figure 6: Categorization of parking spaces in Georgia Tech based on parking location type .....	21
Figure 7: 3D representation of parking spaces in Georgia Tech.....	22
Figure 8: Historical Data sample for Parking Area 2 .....	23
Figure 9: Overview of Android application design.....	29
Figure 10: Android Application interface - screen 1 shows the parking finder application, while screen 2 shows an application to find a route back to the car.....	29
Figure 11: Application design and data flow between components of the Android application .....	29
Figure 12: Dynamic map generation for time of day and parking type - Peak hour for Handicap parking.....	31
<i>Figure 13: Dynamic map generation for time of day and parking type - Non-Peak hour for Regular parking .....</i>	<i>31</i>

## Introduction

**Summary:** Goal of this study was to assess the possibility of having a parking management system which enables visitors to find an available parking space at Georgia Tech. Focus of the study was on locating the handicap parking spaces. As a part of this study, all existing parking spaces were mapped with help of satellite imagery and floor plans, while more than half of those were verified through field visits. Existing parking monitoring systems at Parking and Transportation Services department of Georgia tech were studied to assess the possibility of a real time information system for parking. For demonstrating the proposed solution, an android based application was developed to provide parking availability information to users.

Finding a parking space in a crowded area can be a hassle. Riding around to find a parking space has an adverse impact on the congestion in the area. Some estimates suggest that it amounts to around 30% of the traffic. In case of Georgia Tech, there are multiple areas where visitors can park their cars. However during the peak hours of the day or especially on the game day, it can become difficult to manage the parking. Having a system in place which can automatically keep tabs on availability of parking spaces and keep the visitors informed so that they can be redirected to other parking lots, would help a great deal in reducing the load on parking authorities on these occasions. Some of the tracking solutions for parking spaces also help in enforcing the parking violations. Additionally, for handicap people, it might be an extra burden if they cannot find the optimal place. Hence, developing a solution which will be helpful for handicap people in finding the most convenient parking space is a focus of this project. After a meeting with parking and transportation department at Georgia Tech, the possibility of live feed of the parking data was assessed. To develop a prototype application, historical data for Parking Area 2 was used to estimate parking occupancy levels on campus. This paper attempts to summarize the existing parking facilities at Georgia tech. Following section deals with various technologies currently being utilized in parking

management. Further sections attempt to cover a methodology for implementing such a system in Georgia Tech., which includes the design of an application to help users find an available parking space at Georgia Tech.

## **Existing technology and research**

Through this section, several papers found useful and relevant in this research have been summarized. These papers have been categorized into mainly four sections, namely, (1) Overview, (2) Parking detection & availability, (3) Parking forecast & assignment and (4) smart phone based applications. First section gives an overview of several smart parking systems being implemented in the world. Second section deals with various technologies of vehicle detection and estimating current parking occupancy, while, the third section deals with estimation of level of parking at the time of arrival of the vehicle and parking assignment. Final section of the literature review discusses the existing smart phone based applications for parking management and their functionality.

### **Overview**

A paper by Polycarpou et al (2013) on smart parking solutions talks about a survey performed in Cyprus about the behavior of drivers with respect to parking and their needs. It shows that around 30% of drivers had to search for parking for 11 to 20 minutes. Time spent in searching for parking results in unnecessary traffic ends up affecting the traffic flow on the roads. As more and more people have to search longer, it adds up further in congestion. Around 76 % of drivers suggesting high to very high use of smart phone based applications showing availability information indicates the acceptance of technology in general population. Also, around 40% of population showed interest in reserving the parking in advance for a fee, while more than 60 % drivers showed an inclination towards dynamic pricing. After looking at the trends in behaviors and needs of drivers, following sections will delve into different technologies used in parking management.

## Vehicle detection and Current Parking occupancy

### 1. Sensor based:

Sensors are one of the prominent tools used in vehicle detection for parking management. Research by Guru Prasad et al. (2012) utilizes Fiber Braggs Grating sensors for vehicle detection. This type of sensor is embedded into the ground. As the pressure exerted on the sensor changes, the wavelength of light reflected at the sensor changes as well. With of help of this change, the presence of a vehicle can be detected. In this research, the sensor was placed approximately where the rear wheels of the vehicles would be after parking the spot. The research showed successful implementation of such technology for a prototype of two parking spaces. There are several other research studies which use combination of sensors in detecting vehicle movement and parking spot occupancy. A research by Haoui et al (2008) at Sensys Networks Inc., uses a combination of underground and overhead sensors in estimating parking occupancy. This system consists of several underground sensor nodes (covering an area of 3'x 3'), which use Earth's magnetic field to estimate a vehicle passing over them. For a group of such sensors, an overhead access point is also included in this vehicle detection system. Such an access point will analyze the signals collected at its group of nodes and applies several algorithms to detect the possibility of vehicle passing over the sensor. Essentially, each parking spot would have such a sensor under it. Data from these access points is further accumulated over larger network and used in determining characteristics of the system.

These systems typically end up using a whole lot of sensors which makes the vehicle detection for parking a costly affair. Research by Caicedo on systems such as PARC (Parking Access and Revenue Control) takes an alternate approach at vehicle detection (Caicedo F. 2009). Rather than using the sensors to detect each parking space, this system uses them at key locations so as to divide the overall parking area into smaller zones and calculates the

parking occupancy over such zones. This does result in loss of information, as the occupancy for each parking spot is no longer available. However, in many cases such level of accuracy is not particularly required. Such alternatives do provide a decent alternative which provides useful information at lesser costs.

## **2. Cellphones based technologies for parking occupancy detection**

With onset of smart phones, it is becoming easier to share the information. As many smart phones are fitted with a GPS, it has become easier to understand their movements and with their contribution deduce information about traffic, congestion or even parking. As these technologies do not need any specific physical infrastructure in order to function, they turn out to be the cheapest alternatives for parking. With increasing acceptance of crowd sourcing technologies, such alternatives might end up being the thing of the future.

Research by Lan et al uses GPS, accelerometer and gyroscope to detect the pattern of user's movement in order to deduce where they are walking or driving. Additionally, it utilizes techniques such as map matching, which basically checks if their movement is indoor or outdoor. By modeling the length of user's steps with help of height and speed, their model determines the mode and path of user's travel. A research Xu et al (2013) employs a similar approach in estimating the availability of parking space. They mainly use trained model to estimate the mode of travel and with help of patterns of mode changes (e.g. Car to Stationary to walk), the parking spots are guessed. Again by reversing such patterns, it is car leaving the spot is also modeled. In this research the researchers take this even further by aggregating this estimated parking data over the block group or a particular area and record this data over time. Such data is further utilized in coming up with statistical models estimating possibility of the parking space being occupied. However, these systems do have their own disadvantages, such as reliability of data and even more importantly, the privacy concerns of making the GPS data for personal phones available to a third party. There are



certain non-intrusive cellphone based parking detection solutions such as *Roadify*, as these are more focused on the crowdsourcing part of it that is people have to specifically pick the option that they have parked a car at a place in order for the system to detect. However, depending on large number of people makes the reliability part of it more questionable as not everyone might choose to report their parking status.

- 3. RFID based:** Essentially, these systems use Radio-frequency identification (RFID) technologies to detect the parking spaces available in the area. This is accomplished by saving information about the id for the vehicle on a microchip with an antenna. RFID tag, as these are commonly known as help identify the entering or leaving vehicles. Overhead scanners detect the information on these tags to record the parking status. Generally three types of RFIDs – (1) Active, (2) Passive and (3) semi- passive, are used. Active tags have their own power source and are considered to be better functioning. Although barcode and RFID tags have certain similarities, RFIDs end up being better choice in practice as unlike barcodes multiple RFIDs can be read at the same time, reducing the time of operation. However, passive tags are more common in parking management systems due to their low price. In the research by Ganesan et al. (2007) after utilizing RFID to collect information about availability of parking, it is updated on the web servers periodically for the help of users. This research discusses an automated parking spot allocation system by dividing this task into four components, namely, (1) Serial Port Communicator, (2) Free slot checker, (3) Parking charge calculator and (4) Free slot viewer. It provides a functionality where users can communicate with the system to get results in form of a text message and they will also be able to reserve a spot with help of a specific text message.

## **Parking forecast and assignment**

After looking at several ways of collecting the parking availability information through the previous sections, it is also important to understand the existing research in utilizing this data to make

optimal parking assignment. Research in several approaches in making optimal parking assignments has been covered in this section. One such interesting research is by Horng et al (2012), which uses the travelling direction while allocating the parking spot, along with the parking request by the vehicle, in order to reduce congestion in the surroundings by avoiding unnecessary traffic maneuvers. Cellular automata and cognitive radio module has been used to simulate parking conditions in order to come up with an optimal parking location which will ensure the better performance for the overall system.

Generally, while making such allocations, data about currently available parking spaces are utilized. However, in reality, until the user reaches the parking area from his starting point, the space might have been occupied by some other vehicle. Such situation might end up defeating the whole purpose of this solution. Hence, research into forecasting the demand for parking spaces is required to get the possibility of parking spaces at the intended location being filled up before arrival.

Examples of such research have also been covered in this section. On the other hand, research by Geng et al (2012) focuses on building a parking management system capable of making smart decisions. They suggest that as leaving the decision of where to park after showing the alternatives to user might lead to imbalance in parking utilization. As higher number of drivers might end up choosing going for the lot with most number of parking spaces in the vicinity, making this decision for the drivers based on parameters such as parking availability and parking cost in order to make sure the effective utilization of available parking framework, in a way similar to the Nash equilibrium. Hence to achieve these objectives, researchers have proposed a mixed integer linear program (MILP) problem to determine optimal parking location and reserve that space for the user. To ensure the reservations go as per the plan, physical system has been utilized to indicate another vehicle driving by the same location that the spot has already been reserved by another. This article also suggests grouping the parking spots of similar attributes in an area together in order to improve the user experience. It also uses the source location of drivers and also their destination in

parking allocation by weighing the drivers based on their expected arrival times and performing allocation over several small sections of the larger area under consideration.

For predicting the parking space availability in real time, research such as the one by Caicedo et al (2012) uses discrete choice models to simulate the demand and based on its probability of availability, allocates the demand across the parking infrastructure. It mainly uses two algorithms in this process – (1) Real-time Availability Forecast (RAF) and (2) Parking Request Allocation (PRA). After forecasting the demand based on real time and historical data with help of discrete choice models, RAF uses this demand to generate probabilities for the space becoming empty in the future based on Gamma distribution. PRA uses it to allocate the parking requests. Essentially this model follows the iterative process of allocation, future departure estimation and availability forecasts. After running the model on two scales – aggregate as well as individual, authors did not find significant differences in the computing time. However, the computing time for these processes was indeed found to be really high. If the demand forecasting and allocation process takes a long time it defeats the purpose of doing real time allocation. Alternatively, if higher computing power is used, resources might get stuck in this process.

Research by Klappenecker et al (2014) evaluates another alternative method for forecasting demand for parking by Caliskan et al. (2007) This method estimates possible availability of parking spaces with help Markov chain models and queuing theory by considering the historical data and expected time to reach destination. In analysis by Klappenecker et al, authors mention that the model works well with controlled access parking lots by producing decent computing times. In this evaluation, authors have employed theoretical methods to prove some assumptions held in the model by Caliskan to compare the effectiveness of the allocation models and computing time for the algorithms used.

Fuzzy logic based decision making: Although discrete choice models are really useful, sometimes they can end up taking a lot of computing resources. To address this issue, some researchers have

attempted to use fuzzy logic based decision making to combine the parking availability, future demand and user's requirements and come up with allocations. In one such research by Teodorovic et al (2006), a fuzzy and linear integer modeling based decision making system has been designed to perform parking allocation and revenue management. In this research it was assumed that the future demand patterns for parking are known while performing the allocation. As fuzzy is not commonly considered as a learning system, several scenarios were developed using linear integer programming for parking allocation based on which rules for fuzzy systems were designed. This decision making system was found to be useful in making parking the final allocation decisions. As the linear programming part of it needs to be done prior to implementing the fuzzy decision making, in practice, only the fuzzy decision making algorithm would need to run making the computing times shorter. A research paper by Chen et al (2013) proposes a Fuzzy based parking modeling system, mainly for Park and Ride systems, given user's location the system will suggest the best station to park the car at. They have used travel time and historic parking availability to come up with a fuzzy decision making criteria. Although this system was found to be easily implementable using Android applications, limitations regarding complexity of the fuzzy system remain. It does, however, provide an interesting way for implementing the parking allocation system. Similarly, an article by Leephakpreeda (2007) discusses a fuzzy logic based system in which several other variables such as walking distance to building entrances, parking conditions such as safety, shade etc. were also considered while estimating the best location for parking.

### **Smart phone based applications:**

This section attempts to give an introduction to the existing research in the smartphone based applications and also to some existing parking management solutions. A research by Grazioli et al discusses the complete framework of having a smart phone based user interface for parking management systems and the advantages resulting from it. These researchers made an attempt to implement a complete system consisting of web applications for parking management staff and

web or smart phone based applications for users. It also provides a way for parking controllers to manage the parked vehicles and help them in revenue collection and enforcement. Functions such as enabling users to monitor their parking activity by keeping them informed about the parking duration, utilization of algorithms such as Ray casting algorithm along with GPS precision, integration with apps such as google maps & Foursquare and also enabling users to participate in crowdsourcing activities are some of its strong suits.

Examples of existing solutions:

1. [ParkingMate](#): Smartphone based application. It displays the nearby parking facilities and their rates. It does not show any information about availability of spaces.
2. [VoicePark](#): It simplifies the process to find a parking space by adding the voice search feature. This application guides you to the parking space with voice directions, removing the need to look at the phone and in turn get distracted while driving.
3. [ParkMobile](#): This mobile based app displays the data from parking meters and enables the user to enter the parking id or parking meter number and add time on the meter.
4. [SecureParking](#): This app shows the availability of parking spaces in addition to enabling users to add time one those.
5. [SFPark](#): This application was developed as a prototype for San Francisco in order to improve the parking utilization in the city. Other than displaying the available spaces and being able to pay online, this app enables to have a dynamic pricing module to improve parking utilization.
6. [Merge \(Xerox\)](#): The next two solutions on this list are more sophisticated. Merge is an effort by Xerox to provide an integrated parking solution which can manage people, parking infrastructure and the revenue. It can provide real time parking (collected with help of sensors) availability data to the customer. Additionally, it records this data to determine dynamic pricing of the parking spaces in order to manage the demand better and increase the revenue.

7. [Cisco and Streetline](#): This solution was developed in collaboration of Cisco with streetline. It combines streetline's sensor based solutions with Cisco's Camera based solution in order to collect data. As a part of this effort a City information System is also being proposed to expand the use of the system for other uses such as smart lighting, video surveillance etc.
8. Android, where is my car? (App Inventor)  
Developed at MIT, this is yet another example of simple but highly useful mobile application pertaining to parking. It enables the user to store the location of parking so that at a later point of time, it would be easier for the user to find their car easily. Use of this application comes to fore during events such as concerts, games or other such events where the parking is spread over large areas. Basically, when we are visiting some place for the first time and are not accustomed with the parking arrangements, this app will help in tracing back the location of the car. It uses link with google maps to calculate the path between the current location and the remembered location of the car.

## Existing Parking Infrastructure

Before going into the real time parking management systems, I wanted to get some perspective on the existing parking infrastructure in Georgia Tech. By studying the existing infrastructure, overall requirements would be assessed in order to have a Georgia Tech wide parking management system. Decisions on the type of parking availability detection systems to be used, the parking allocation methods to be used and the way this data is to be shared would be made after studying this data. For this purpose a three phase data collection procedure was sketched out. Following are the data collection phases used in this process:

1. Satellite imagery based data collection,
2. Floorplan based data collection and
3. Field verification

Following sections discuss these data collection methods in detail and describe the data collected through this exercise.

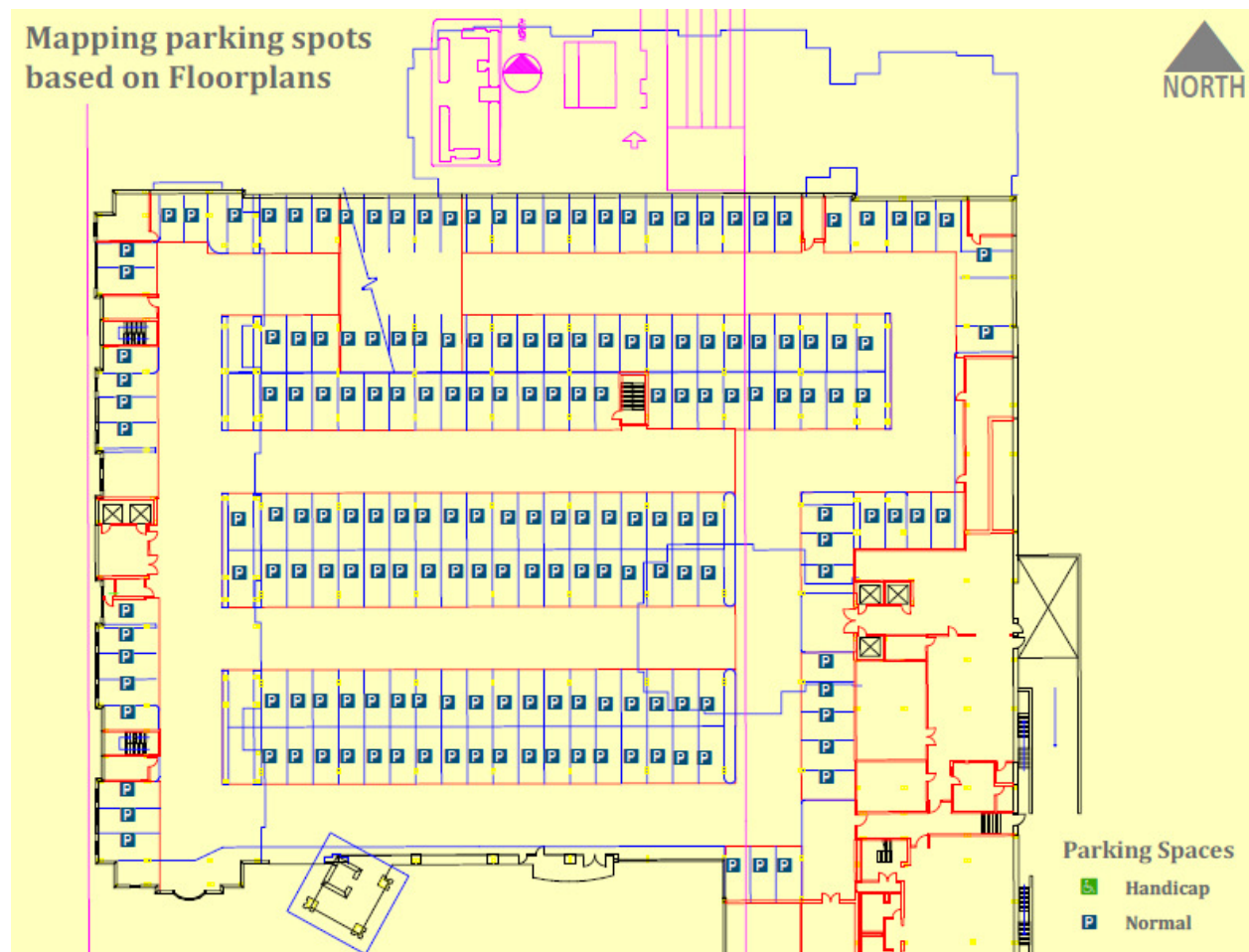
### Data collection

First phase involved getting an overview of available parking spot using satellite imagery of the Georgia Tech campus. An attempt was made to identify whether the spot was reserved for handicaps based on the markings on the parking spot. For places such as covered parking lots, for which it is not possible to get data about parking space and their types from satellite imagery, floorplans were used to mark the parking spots. Third phase consisted of making field visit to these spots and making corrections if any and recording additional information. As a part of this phase, other parking characteristics such as additional parking types, parking location types and any other relevant data were gathered. Images 1 & 2 serve as examples of data collection phases 1 and 2 respectively. Status of phase 3 has been showed in data overview subsection.



*Figure 1: Phase 1 - Mapping parking spots based on satellite imagery. Map shows the parking spots near Institute of Paper Science and Technology*





*Figure 2: Phase 2 - Mapping parking spots using floor plans. Map shows parking spots at the parking garage at North Avenue Apartments*

## Data Overview

As a result of data collection, around 13000 parking spots in Georgia Tech campus have been mapped. Out of which around 268 parking spots were observed to be handicap parking spaces (image 3). This number might change slightly depending on the verification of the remaining parking spaces. As of now, most of the surface parking spaces have been verified. However, some of the parking spaces in covered garages are yet to be verified (image 4). Based on the categorization by the department of Parking and Transportation at Georgia Tech, these parking spaces were categorized into zones. With main categorization being: (1) East zone, (2) West Zone, (3)

Residential zones, (4) Visitor Parking, (5) With capability of paying online (pay by cell) and uncategorized parking spaces (image 5). Based on the field survey, information on the type of parking location was also gathered. Using which image 6 was prepared to show whether the parking spot is a part of street parking, garage or parking lot. While collecting the data, information regarding the floor on which the parking exists was also gathered, using which a 3D representation of the parking has been shown in image 7. Different colors represent variation in height. All the parking on the ground floor was given the height of 0.

For the next section a summary of parking location type might be useful. The following table shows the distribution of parking spaces in Georgia Tech over the Covered Garages, Street parking and Parking lots (table 1). Georgia tech issues tags similar to RFIDs to the students, faculty and staff who have signed up for parking. The covered garages and some of the parking lots are access controlled, with access to only those who have signed up for the parking. All the visitor parking lots have parking meters, for some of which online data might be available as those are catered by the ParkMobile application. Some of the on street parking spots are also covered by ParkMobile, making those available for smart phone based management.

*Table 1: Distribution of parking as in types of parking locations*

<b>Parking location type</b>	<b>Count</b>
Covered Garage	6349
Street	1293
Parking Lots	5657
Others	10

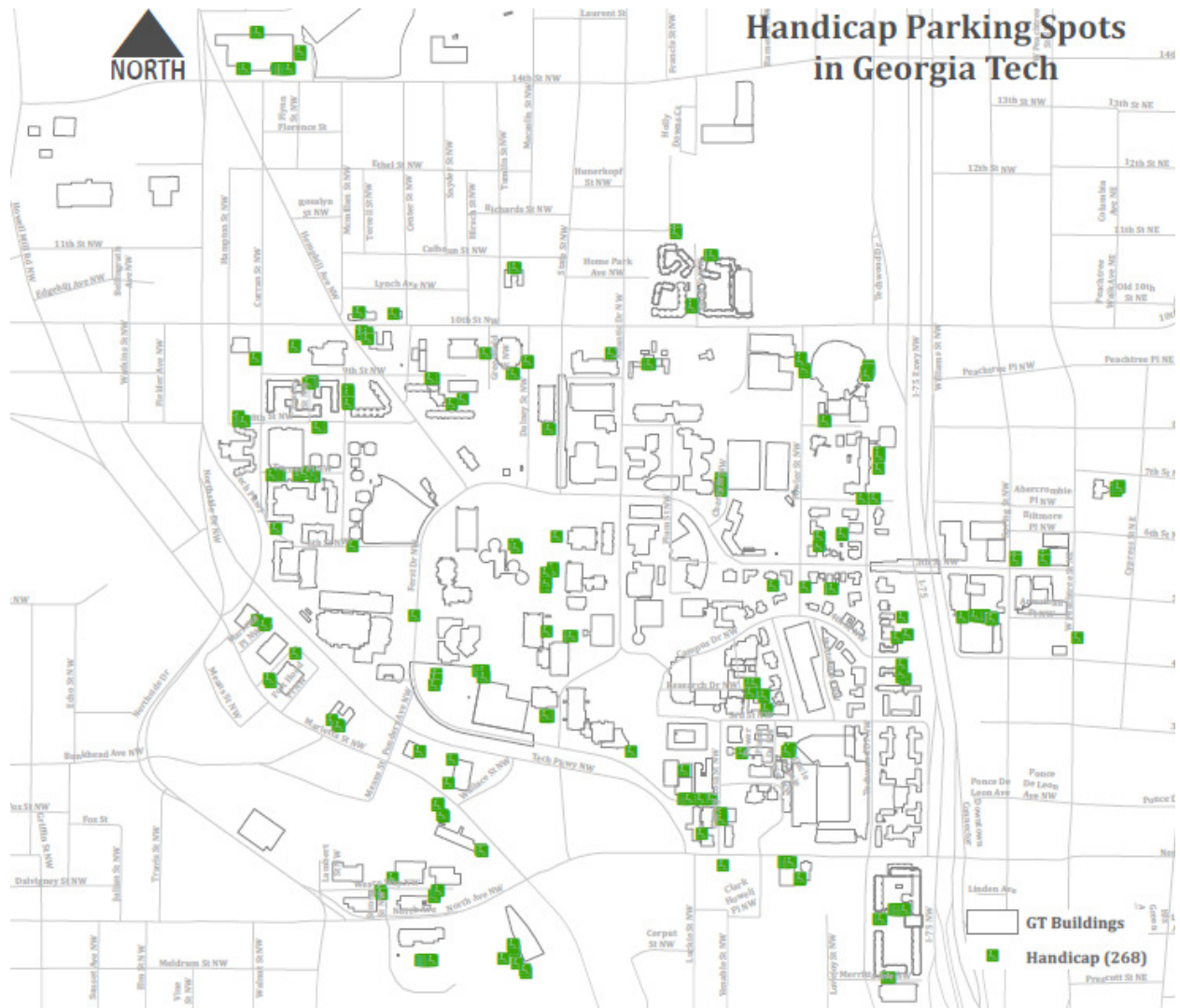


Figure 3: Handicap parking spaces in Georgia Tech's campus

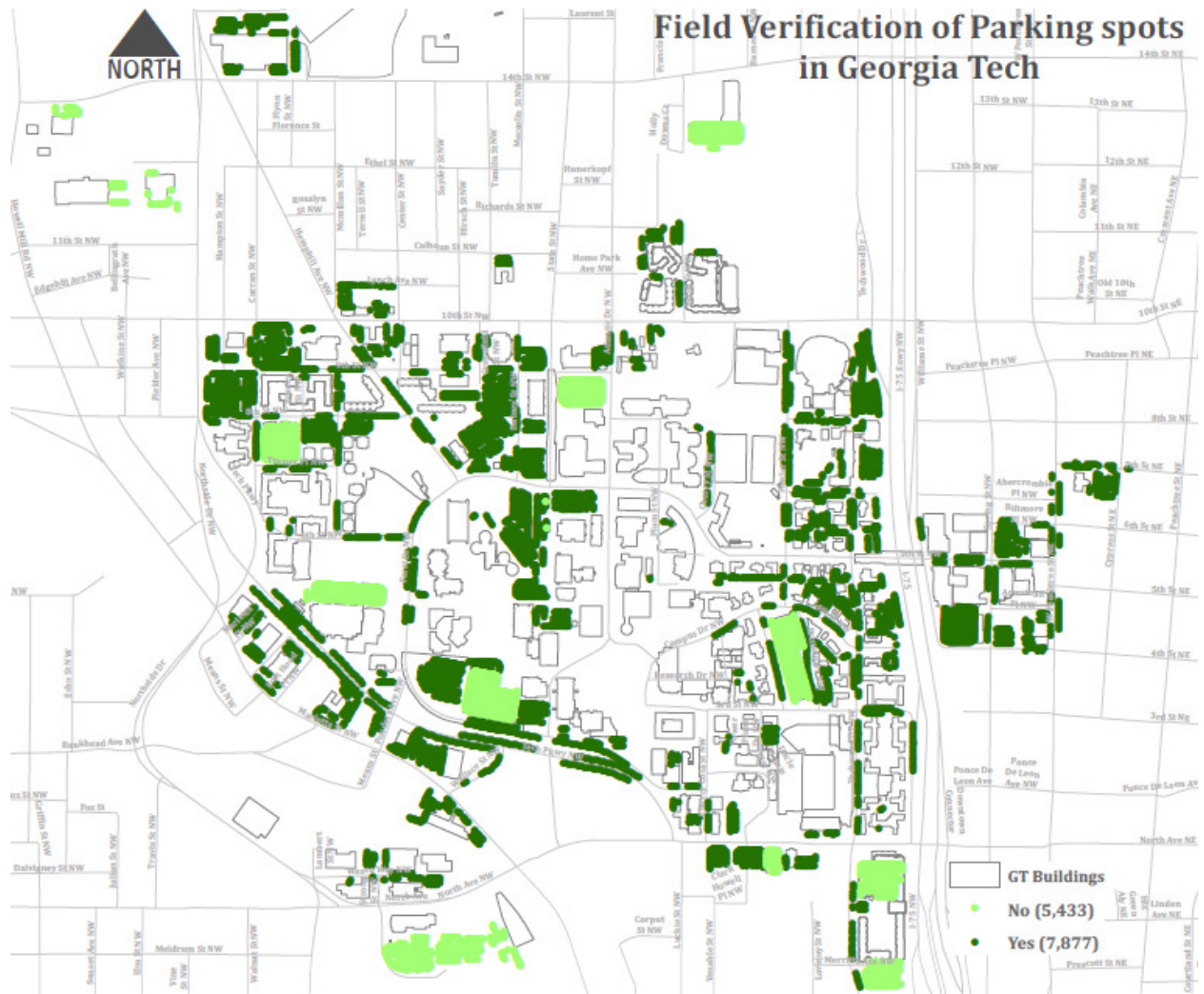


Figure 4: Verified parking spaces in Georgia Tech's campus

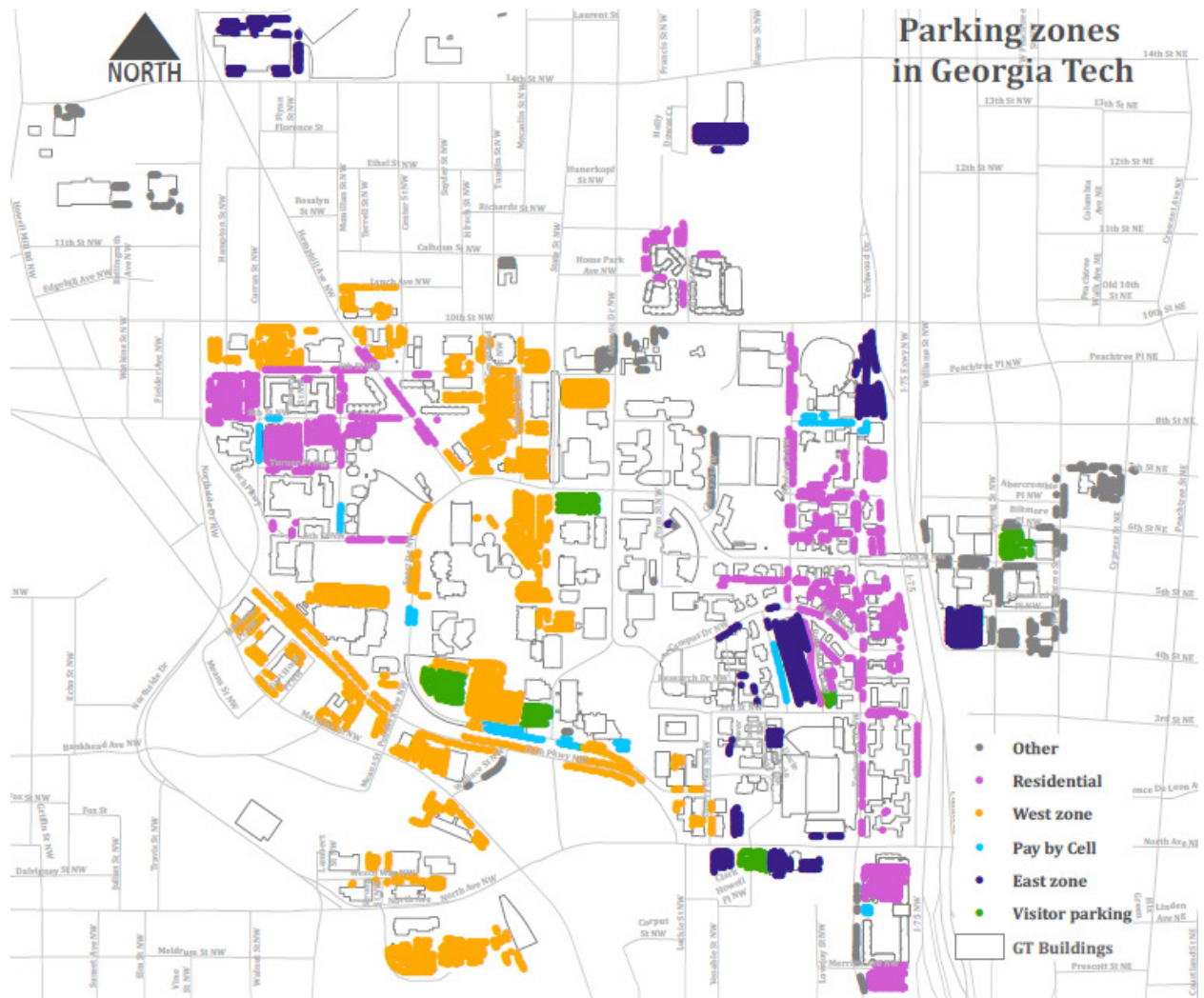
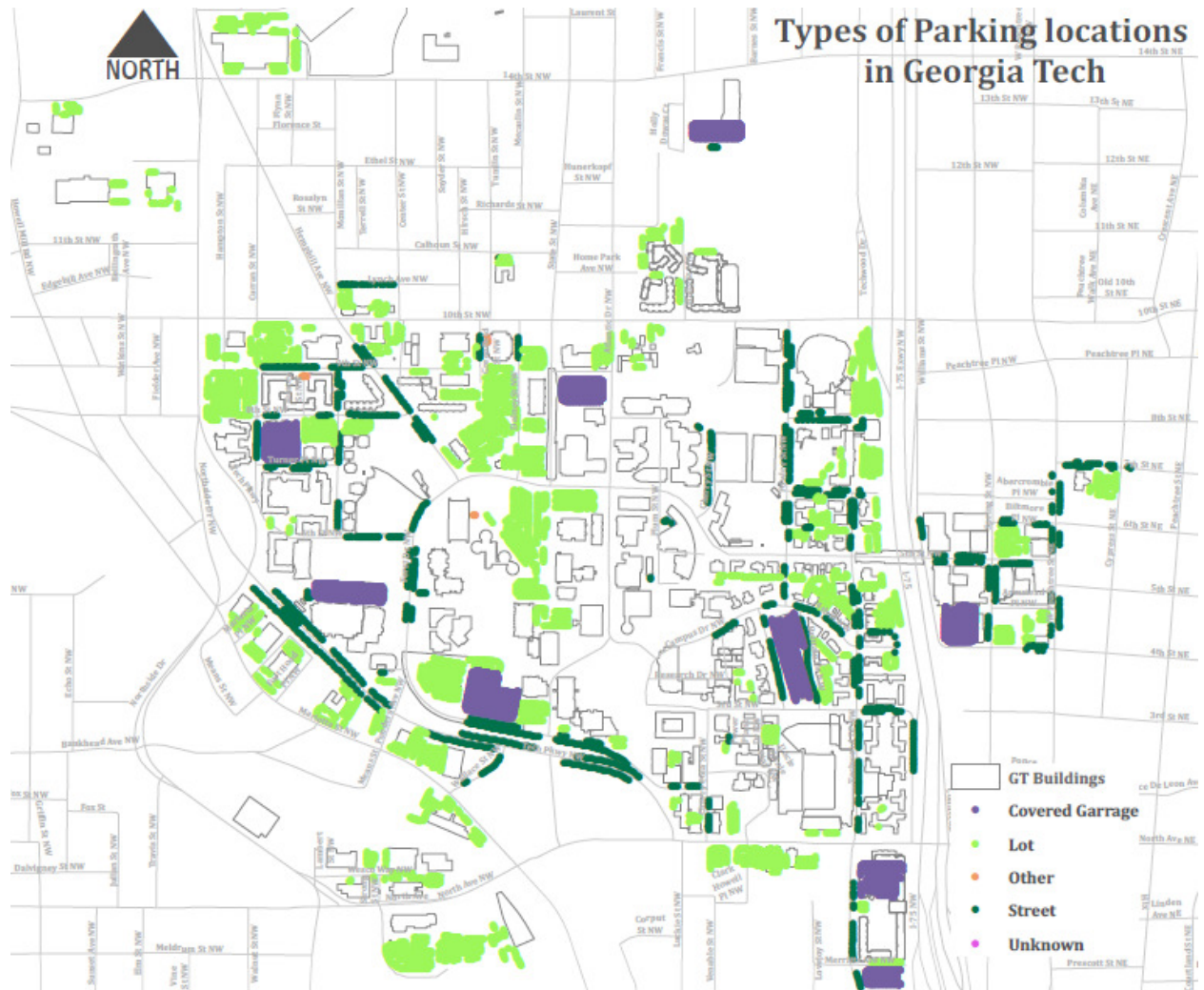
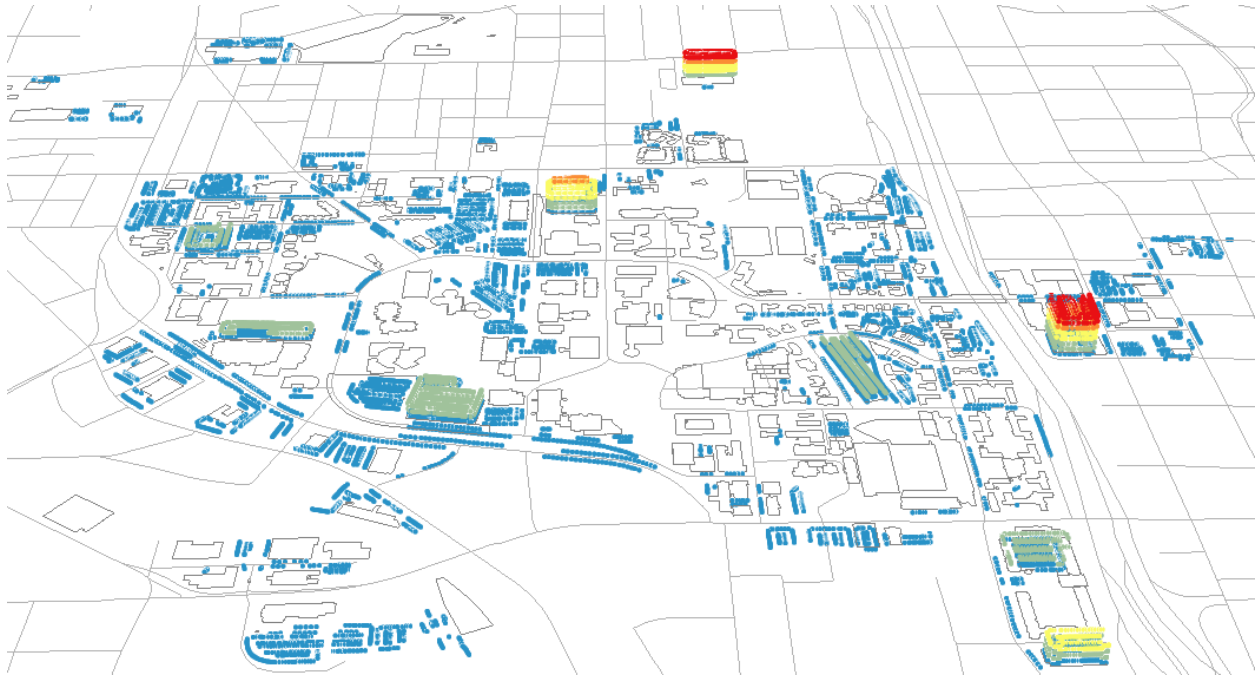


Figure 5: Parking zones in Georgia Tech



*Figure 6: Categorization of parking spaces in Georgia Tech based on parking location type*



*Figure 7: 3D representation of parking spaces in Georgia Tech.*

### **Existing Real-Time Parking Monitoring Systems**

As discussed in the existing parking infrastructure section, Georgia Tech has various types of parking spread over a large area. Some of it is access controlled while some of it is not. A portion of it is under parking garages while the rest of it is spread over open parking lots and street parking. As a result of this diversity in parking, it would be difficult to use the same method of vehicle detection to cover the whole campus. Of course, using sensors for each parking spot might be one of the solutions but the high cost of such a method prevents it from being a decent solution. Hence, we need to implement different technologies depending on the type of parking in order to be able to detect the parking occupancy levels. As the covered garages are access controlled, getting access to their identification sources and parking details data would make it easier to develop the app. As the users with access to these garages already have tags which differentiate them, recording the data for people with handicap parking space permits would help in making this data available to public. These garages currently use variable message systems to show if they are full. Parking and Transportation services at Georgia Tech use SCAN servers to track the parking activities in the





## **Proposing a prototype**

After understanding the parking infrastructure in Georgia Tech, the next step is to consider several technologies in order to come up with a solution for parking management for the campus. The parking management solution was divided primarily into two verticals – (1) Back end and (2) Front end.

### **Back End**

Back end part of the solution covers the parts that user does not have direct interaction with. This part is the backbone of the overall solution. All the computing intensive, data intensive tasks are expected to be performed as a part of this solution. It mainly consists of the Vehicle detection & parking occupancy management systems and Parking assignment methods.

Having some additional overhead sensors installed in such garages in order to divide them into sub-sections would help in giving directions to users in finding their parking space. As far as visitor areas are concerned, we just need to make the metered data online so as to use it in determining the parking occupancy. Challenging part is to monitor the street parking spaces. Out of these spaces, the metered ones would be easier to get access to. However, the rest of the spaces would need additional measures in order to make their occupancy available online. Methods such as embedding sensors for each such space would again prove to be really costly. Methods such as video based detection or infrared based detection might be useful in this regard. As our goal is to provide detailed information on handicap parking spaces, these would need to be embedded with sensors so as to recognize their occupancy.

### **Parking Assignment**

Parking assignment puts an interesting tread-off in front of us – whether to go for accuracy, speed or making it widely usable. The models with higher accuracy sometimes end up being slower as seen with the discrete choice models. Similarly, relying on user’s computing power might again

make it useless for a section of users without such capacity, while implementing simpler methods might lead to system being unreliable at times. To counter this effect, we can combine the advantages of these three systems. For example, if the extensive analysis about the prediction of occupancy levels based on historic data might be run periodically on the back end so as to determine certain coefficients denoting the expected occupancy levels based on time of day events. This will make it easier in computation, as we only need to consider these fixed coefficients for that time along with the current data so as to come up with possibility of finding parking at the intended time. As these calculations are being performed on back end, it will not put additional load on user's smart phone.

## **Front End**

This part of the solution covers the user's end of the solution. Along with the user interface, it also includes, the way this information is going to reach the user and also the focus of the solution.

Central part of the solution is to give the user information about the parking spaces available and give them an option to look for handicap parking spaces. The application will ask for the destination the user wishes to go to and finds the optimal parking spaces nearby based on expected parking availability at the time of arrival.

## **Smart phone application**

For creating smart phone application, the focus in this project is mainly on Android based application. Services such as those by Esri and Google were explored for developing a smartphone based application. Esri provides a functionality to utilize its services published via ArcGIS Server on android based applications. It enables us to use the tools such as network analysis on android. As the extensive network of sidewalks is only available as a shapefile, it might prove to be an asset if we utilize it in making this app. It might enable us to use a combination of cost factors based on this sidewalk network while making decisions about best route from parking spot to their destinations.

Google maps engine will be used along with the APIs while configuring an application using Android. It is being linked with the google maps so as to provide proper directions to the user, as google maps is a commonly used navigation application among the smart phone based tools. Initial version of the tool was developed using the App Inventor tool developed by MIT. It is scratch language based tool which provides a graphical user interface for developing android applications. Block based structure of developing applications makes it easier for the developer to comprehend the structure of the application and the data flow. However, using in-built module does have its own challenges. One of the main issues can be lack of flexibility which might hinder building more sophisticated apps using this platform. However, for the basic applications, it is a highly useful platform. To demonstrate the use of android based applications in providing parking related data, App Inventor platform was used in this study.

## Designing a smartphone application

To demonstrate a way of managing parking data for Georgia Tech's campus, an android application was created. This section deals with the design of the application and attempts to explain one of the ways of managing and sharing the parking data. The android based application for parking was devised based on mainly following four modules – (1) Choosing Destination, (2) Dynamic parking availability, (3) Routing and (4) Additional services. For managing the data flow in this application various types of strategies were used depending on the requirement. Figure 9 shows data management strategies used in the application, while figure 11 shows the design and data flow in the application. Figure 10 on the other hand, shows the screenshots of the current working application.

- **Choosing Destination:** Focus of this module was to make it easier for the application user to specify their destination. Searching for the address of their destination might not always be the best choice, especially as they might not know the exact address of the place they

might intend to visit on Georgia tech's campus. Destination related details were extracted from a web based table which stores the names and locations for facilities at Georgia Tech. Destination module in this application provides the user with a list of popular activities such as Football or Basketball game along with Major departments and offices on the campus. Application takes the user input for name of their destination and fetches the location details from the stored table. Additionally, user input is also requested to know whether they might be looking for handicap parking spaces on the campus.

- **Dynamic Parking Availability and Data Visualization:** For demonstration of the application, historic data for Parking Area 2 was used for estimating parking availability based on time of day. The application records the current time to populate the parking data. Currently, the parking availability uses a web based table similar to that of the Destination. However, to make it possible to add real time data to the application, fusion table functionality is being explored at the moment. For the purpose of this application, the data was divided into two categories – (1) Peak hour (9 AM to 5 PM) and (2) Non-peak hour (5 PM to 9 AM).

Parking availability for these durations was estimated from the provided historical parking availability data for parking area 2. Availability for rest of the parking areas was estimated by assuming an occupancy rate similar to parking area 2. In future, functionality of this tool can be improved by making the data available for more frequent intervals (e.g. hourly). Based on the time of request, their preference about handicap parking and the historical data, appropriate parking availability data is populated. Preference about the handicap space requirement is used to filter out the parking areas without any handicap parking spaces. Even though, the occupancy for handicap parking spaces is not currently specifically monitored, an attempt was made at estimating their availability by assuming their occupancy percentages might be similar to that of regular parking. Availability of handicap

parking spaces is estimated by assuming occupancy levels, similar to those of parking area 2. Figure 12 shows an example of such a dynamically linked map for finding handicap spaces in peak hours. Similarly, figure 13 shows the map for overall parking availability in non-peak hours. Using these details, user can make a decision about the preferable parking area based on their proximity to their intended destination and availability of parking.

- **Routing:** Routing module intends to provide two solutions to the user – (1) driving directions and route from their current location to their preferred parking location and (2) walking directions from parking location to their intended destination. Google APIs were used to estimate the route and directions. This functionality will help them integrate their experience of finding a suitable parking space on campus and finding directions to it. Added functionality of finding a walking route to their destination from their car might further improve their experience.
- **Additional Services:** While going to a game or a performance or for that matter any place you are not completely familiar with, finding an available parking space is just one leg of the problem. Many times, remembering where exactly was the car parked can waste some time. To counter this issue, parking application also provides a way of remembering the location where you have parked your car and find an optimal route from your current location. This module was developed in similar way to the Android, “Where is my car application?” developed at MIT. The application saves your location details on a local database upon pressing the “remember this location” button. Local database is used here for storing location details instead of a web based database to protect the privacy of the user. After the user’s purpose of visit is fulfilled, they can press the “Get me to my car” button to find a route back to their car.

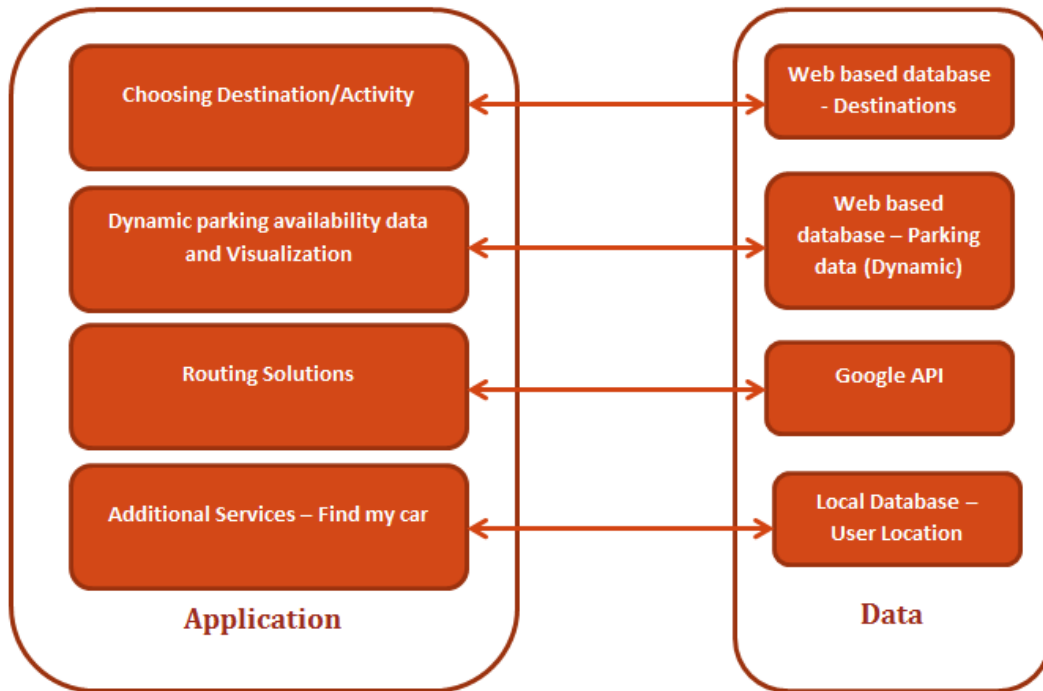


Figure 9: Overview of Android application design

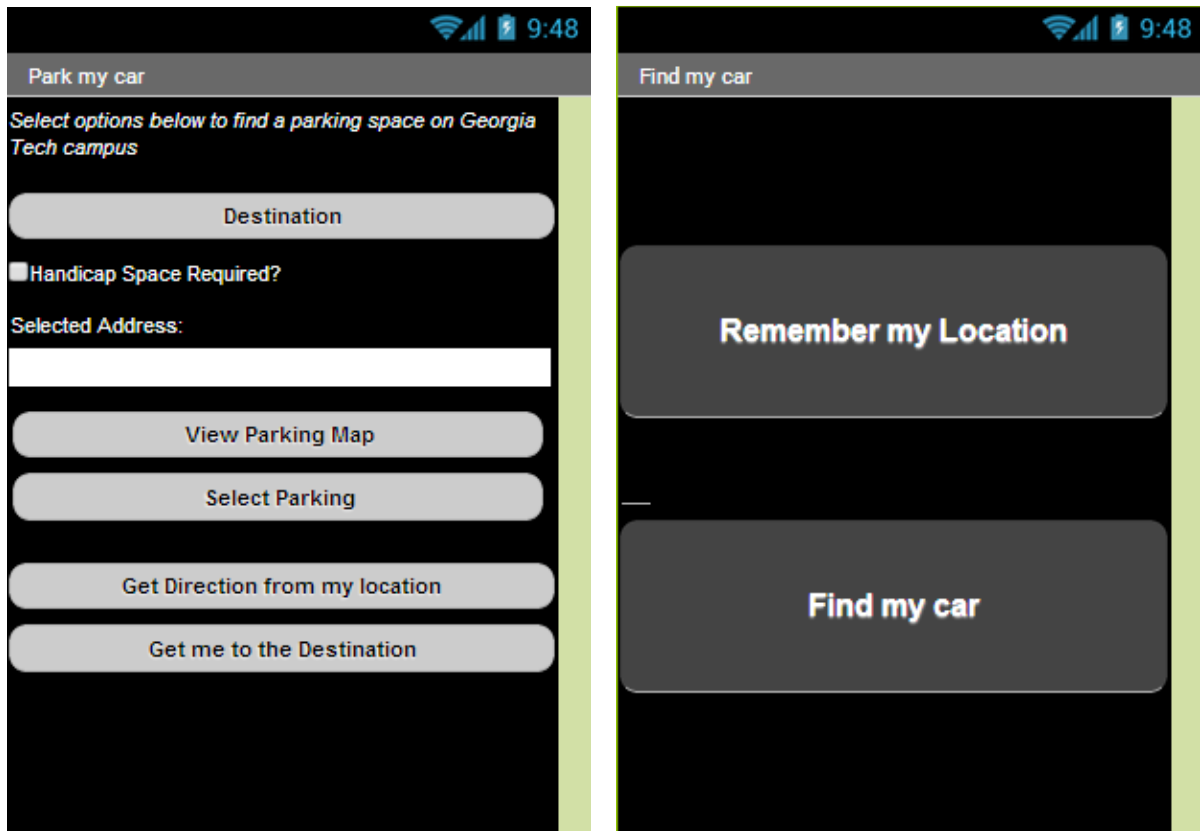
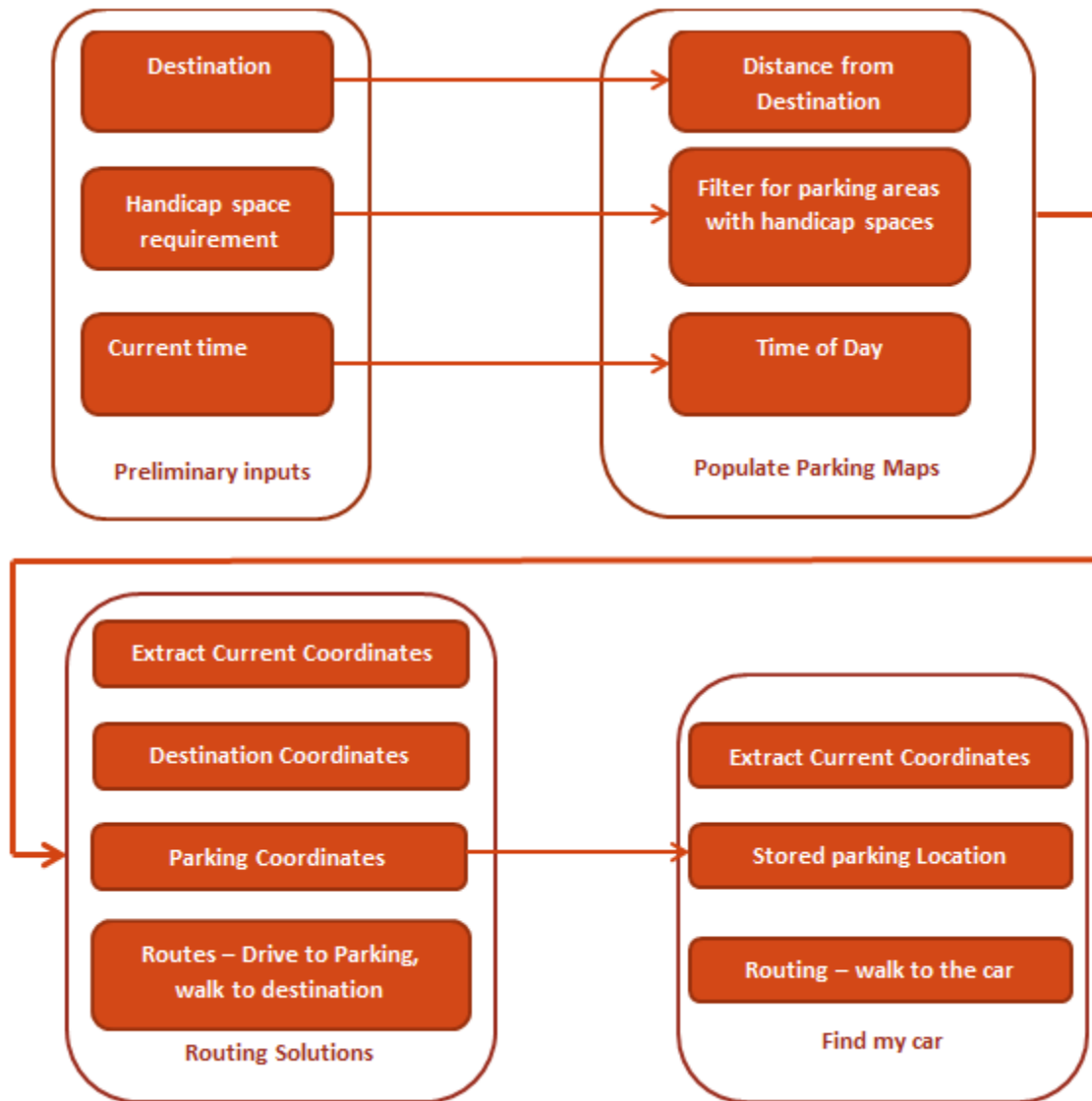
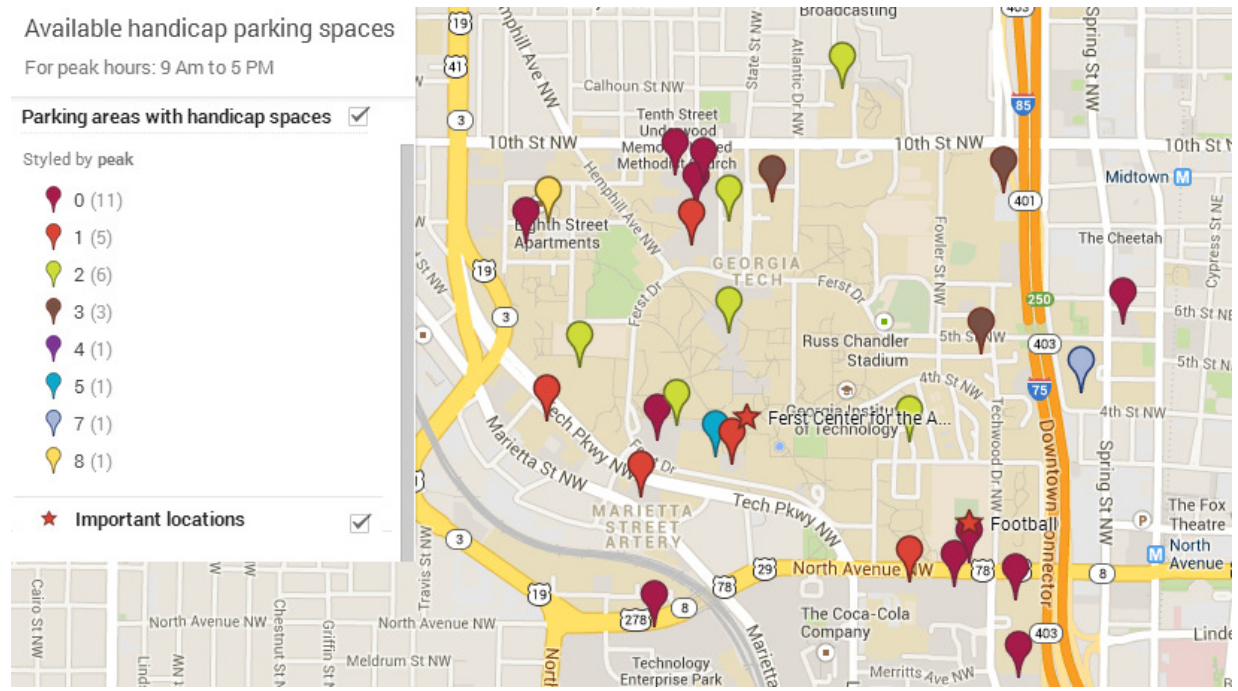


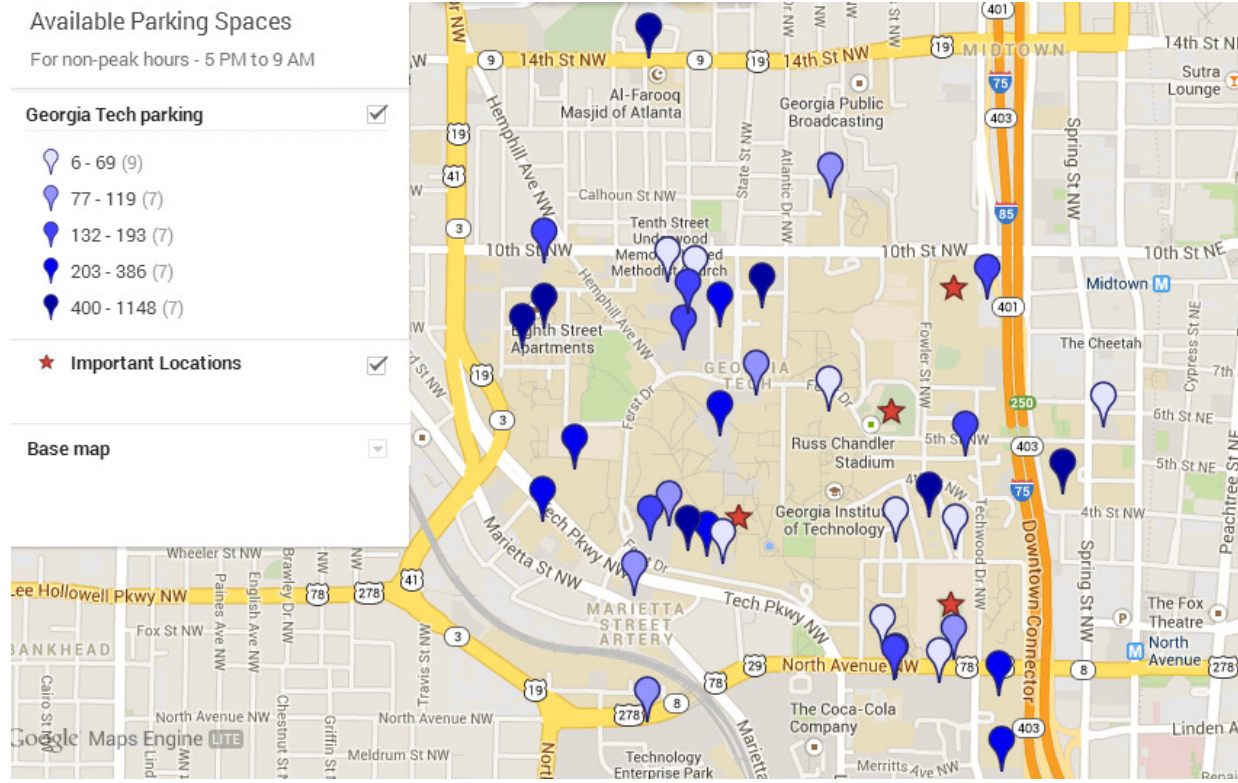
Figure 10: Android Application interface - screen 1 shows the parking finder application, while screen 2 shows an application to find a route back to the car



*Figure 11: Application design and data flow between components of the Android application*



**Figure 12: Dynamic map generation for time of day and parking type - Peak hour for Handicap parking**



**Figure 103: Dynamic map generation for time of day and parking type - Non-Peak hour for Regular parking**



## Conclusions

Studying the existing parking infrastructure is important in understanding its scale and spread over the area. Having a detailed information about the parking facilities at Georgia Tech would help in deciding between various options for parking management systems by picking the one most suitable to the parking needs on the campus. Additionally, developing spatial inventory of all the parking spaces on campus further opens up avenues for improvements in future. An example of possible future application can be to provide 3-dimensional information about parking facilities to visitors by with help of the floor numbers.

Using the collected data and historical occupancy data from Parking and Transportation department, a prototype application was developed. It shows that the existing parking management infrastructure at Georgia Tech can be utilized to develop a system for monitoring and sharing parking availability information. However, the methodology proposed in this study has certain limitations. Monitoring real time feed for each parking space is not really feasible with the current infrastructure, as the real time data is available on aggregated level. This paper also suggests some solutions for monitoring handicap parking spaces. Application developed in this study can only use the historical data to estimate parking availability. However, ongoing work on the project to move to a fusion tables might enable the application to utilize the real time information as well.

## References

- Guru Prasad et al (2012). 'Fiber Braggs Grating Sensor instrumentation for parking Space occupancy management'. 2013 international Conference on Optical Engineering.
- Haoui A. et al (2008). 'Wireless magnetic sensors for traffic surveillance'. Elsevier journal. Transportation Research part C 16. Pages 294 – 306
- Geng et al (2012). 'A new "Smart Parking" System infrastructure and Implementation'. 15<sup>th</sup> meeting of EURO Working Group on Transportation, Elsevier Publications, Procedia – Social and Behavioral Sciences 54. Pages – 1278 – 1287.
- Lan et al. (2014). 'An intelligent driver location system for smart parking'. Elsevier Publications, Expert Systems with Applications, pages – 2443 - 2456.
- Leephakpreeda T. (2007). 'Car-parking guidance with fuzzy knowledge-based decision making'. Building and Environment 42 (2007) 803–809
- Horng G. et al. (2012). 'Using Cellular Automata on Recommendation Mechanism for Smart Parking in Vehicular Environments'. IEEE 978-1-4577-1415-3/12.
- Grazioli et al. (2013). 'Collaborative Mobile Application and Advanced Services for Smart Parking'. 2013 IEEE 14th International Conference on Mobile Data Management. 978-0-7695-4973-6/13
- Polycarpou E. et al. (2013). 'Smart parking Solutions for Urban Areas'. 978-1-4673-5828-6/13/\$31 ©2013 IEEE.
- Chen Z. et al (2013). 'Development of Fuzzy Logic Forecast Models for Location-Based Parking Finding Services'. Hindawi Publishing Corporation. Mathematical Problems in Engineering. Volume 2013, Article ID 473471, pages 6
- Huayan S. et al. (2007). 'Empirical Study of Parking Problem on University'. J Transpn Sys Eng & IT, 2007, 7(2), 135–140.
- Klappenecker et al. (2014). 'Finding available parking spaces made easy'. Ad Hoc Networks 12 (2014) 243–249.
- Joshi P. et al. (). 'Global Review Of Parking Management Systems & Strategies'. 2012 Northeast Decision Sciences Institute Conference Proceedings. Pages 477 – 496
- Teodorovic D. et al (2006). 'Intelligent parking systems'. European Journal of Operational Research 175 (2006) 1666–1681
- Vianna M. et al. (2004). 'Intelligent transportation systems and parking management: implementation potential in a Brazilian city'. *Cities*, Vol. 21, No. 2, p. 137–148, 2004

- Barata E. et al. (2011). 'Parking at the UC campus: Problems and solutions'. Cities 28 (2011) 406–413
- Giuffre T. et al. (2012). 'A novel architecture of parking management for Smart Cities'. Procedia - Social and Behavioral Sciences 53 ( 2012 ) 16 – 28
- Mei Z. (2012). 'Analysis of Parking Reliability Guidance of Urban Parking Variable Message Sign System'. Hindawi Publishing Corporation. Mathematical Problems in Engineering. Volume 2012, Article ID 128379, 10 pages
- Caicedo et al (2012). 'Prediction of parking space availability in real time'. Expert Systems with Applications 39 (2012) 7281–7290
- Xu et al (2013). 'Real-time Street Parking Availability Estimation'. 2013 IEEE 14th International Conference on Mobile Data Management. 978-0-7695-4973-6/13 \$26.00 © 2013 IEEE
- Caicedo F. (2010). 'Real-time parking information management to reduce search time, vehicle displacement and emissions'. Transportation Research Part D 15 (2010) 228–234
- Ganesan et al. (2007). 'Automated Parking Slot Allocation using RFID Technology'. 1-4244-0779-6/07/\$20.00 ©2007 IEEE
- Caicedo F. (2009) 'The use of space availability information in "PARC" systems to reduce search times in parking facilities'. Transportation Research Part C 17 (2009) 56–68
- Qin et al. (2013). 'An intelligent parking system based on GSM module'. Appl. Math. Inf. Sci. 7, No. 1L, 55-59 (2013)
- Caliskan et al (2007). 'Predicting parking lot occupancy in vehicular ad-hoc networks'. 65th IEEE Vehicular Technology Conference, VTC 2007, IEEE Press, Dublin, Ireland, 2007, pp. 277–281.
- App Inventor. Massachusetts Institute of Technology – <http://appinventor.mit.edu/explore/>
- Cisco and Streetline: <http://www.streetline.com/2013/10/streetline-and-cisco-expand-collaboration/>
- Voice park: <http://www.voicepark.org/>
- SecureParking: <http://www.secureparking.com.au/>
- ParkMobile: <http://us.parkmobile.com/members/>
- SFPark: <http://sfpark.org/>
- Merge: <http://news.xerox.com/news/Xerox-Merge-Parking-System-Makes-Transportation-Easier>