# A Parking Management System based on Background Difference Detecting Algorithm

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***Abstract*—The number of vehicles in cities has increased dramatically due to rapid economic development. However, the infrastructure for accommodating these vehicles has grown relatively slow. Alleviating the pressure on the urban transport system and solving the 'parking difficulty' problem have thus become hot topics recently. In this paper, an intelligent parking system based on geomagnetic field variations is presented to solve this problem. An algorithm which detects the presence of vehicles in parking spaces in a parking lot is designed and field test results are presented. Our results show that this system has an acceptably high accuracy with low cost, high feasibility, high efficiency and hence is recommended for wide use.**

***Index Terms*—urban transport system, parking difficulty, parking system, geomagnetic field.**

## I. Introduction

With the rapid development of the economy, vehicles have become an indispensable tool in people's daily life. However, solving the 'parking difficulty' problem is now an emergent issue. Detecting the status of parking spaces in a parking lot is the most fundamental prerequisite in modern intelligent parking management and guidance systems.

In order to acquire accurate information of parking status, a magnetic field sensing technique is adopted to detect magnetic variation in the parking spaces in real time, since ferromagnetic materials are easily magnetized when placed in a magnetic field and magnetized ferromagnetic objects (for example, vehicles) are capable of changing the surrounding geomagnetic field.

The contribution of our work is three-fold.

(1) We choose a kind of effective and innovative sensors to detect the parking status, which could be further leveraged for smart parking system design.

(2) We propose a simple but very effective detective algorithms for this parking system.

(3) We make an extensive experimental study on our propose parking system. The evaluations include the accuracy, robustness, susceptibility, stability, etc.

The rest of the paper is organized as follows. We briefly describe preliminary knowledge of some existing smart parking systems and summarize the disadvantages of them in Section II. And Section III introduce the hardware frames of our smart parking system. After describing our algorithm design in detail in Section IV, we analyse the performance of our algorithm based on multiple factors in Section V. Finally, we conclude the work in Section VI.

## II. Related Work

Recently, much work has been done based on wireless smart parking techniques. In the following sections, several widely used smart parking techniques will be briefly introduced and their disadvantages will also be indicated.

RFID technique normally consists of RFID readers, RFID writers, RFID tags, RFID car-code scanners, RFID smart sensors and RFID controllers [1]. In RFID based parking systems, vehicles are identified and parking-lot fees are collected automatically without any personnel [2].

Some research has been done on RFID based smart parking systems. In [3], L.X. Wei and Q.S. Wu designed and implemented a smart parking management system based on the RFID. In [4], Z. Pala and N. Inanc provided a solution for the problems of parking-lot management systems via RFID technology.

Ultrasonic sensing techniques have become popular in recent smart parking systems. These techniques place an ultrasonic generator on top of a parking space. When a vehicle enters the space, the reflected ultrasonic is received by the generator, determining that this parking space is no longer available and the status is "occupied".

W.J. Park and B.S. Kim have used ultrasonic sensors to deal which parking space detection with increased the detection accuracy [5]. Abdel-Hafez, M.F. and Nabulsi, A.A. have presented a sequential fault detection and identification algorithm and applied it to ensure accurate operation of a vehicle's ultrasonic parking sensors [6].

Electromagnetic induction coil techniques are very mature. When a car passes over a buried induction coil electric current is generated in the coil via the change of the electromagnetic

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field caused by the car's metal components. By monitoring this current change, it is easy to detect if there is a car present on the parking space.

Although the aforementioned traditional smart parking systems have been widely studied and applied in practice, these systems suffer from many disadvantages. These systems depend heavily on the external environment, including temperature, humidity, and the electromagnetic environment.

The disadvantages are summarized in Table.1. In general, traditional parking systems are susceptible to degradations due to environmental factors and have relatively high deployment costs [7].

## III. System Overview

To remedy these problems, a 3-Axis Digital Compass IC, the most advanced technology of its kind, is adopted to determine parking space status. An algorithm, Background Difference Detecting Algorithm based on Environment Learning (BDDAEL), uses the determined parking space status information to efficiently solve the aforementioned problems. The entire system architecture is shown in Fig. 1.

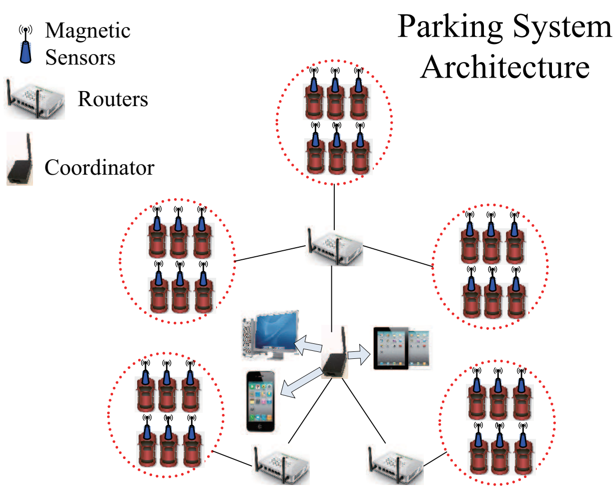



Fig. 1. Parking Space Detection System.

In this system, the Honeywell HMC5883L ($3-Axis$ Digital Compass IC) is used to detect the geomagnetic field value of the parking space. Detailed specifications of HMC5883L are presented in [9]. Firstly, magnetic sensors which are capable of detecting geomagnetic variations are placed in each parking space, through which the status of the parking spaces can be easily determined. It is worth noting that, because the batteries need to be changed periodically, the magnetic sensors are fastened to the ground surface, instead of burying in the ground. This leads to lower deployment and maintenance costs (e.g., battery change) compared to traditional parking systems. Magnetic sensors are made from compressive materials which are very small and are placed in the center of each parking space. Hence it is relatively hard to crush them, even when the vehicle is driven by an inexperienced driver. Then by using Zigbee technology [8], the status information is wirelessly transmitted and displayed on computer screens, which is very convenient for the drivers and employees of the parking lot.

In the system described here nodes are battery powered. A reasonable power management schemes is designed to extend the lifetime of the battery, including a system sleeping schedule and battery testing & alarming. Fig. 2(b) shows the Zigbee coordinator and a single end-device which is used in our system.

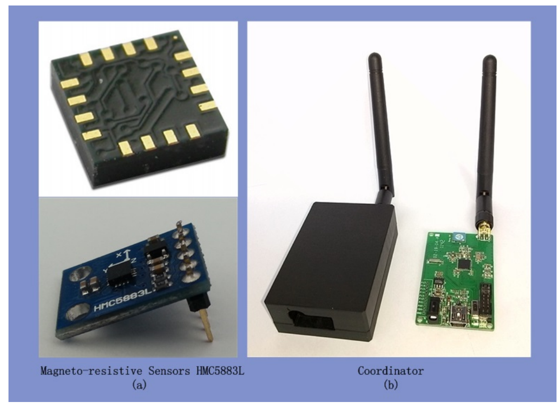



Fig. 2. Magnetoresistive Sensors HMC5883L and Zigbee Coordinator.

### A. Research Contents

Wireless networking technology is a very mature technology with the development of wireless sensor networks [10]. In the system presented in this paper, Zigbee based technology is utilized to rapidly construct a wireless network and change the number and the status of parking spaces as required [11]. The key enabler of the parking status detection system is how precisely the lot status can be measured. In our system, magnetic sensors distinguish the status of parking spaces via the change of geomagnetic fields, which nearly instantly varies due to metallic materials.

## IV. Algorithm

### A. Signal Characteristics Analysis

Assume motorcycles and bicycles are not permitted to park at the vehicles' parking spaces and everyone follows the parking space lines when parking his or her vehicle. Our experiments include an underground and an above ground parking lot environment and vehicles both driving forward into and backing into the parking space. In these field experiments only one magnetoresistive sensor is placed in the center of the parking space. In the experiment, the same car drives forward into and backs into this parking space twice. The data collected by this magnetoresistive sensor are shown in Fig. 3. The blue, red and green lines stand for $x$-axis, $y$-axis and $z$-axis, respectively.

From Fig. 3, it is obvious that the signal is steady when no vehicles are nearby. But when a car drives into a parking space, regardless of forward or backward motion, the magnetic field values of all 3 axes change dramatically. After the car

TABLE I
DISADVANTAGES OF TRADITIONAL SMART PARKING SYSTEMS

| Traditional Systems | Disadvantages |
|---|---|
| RFID | 1. Low anti-interference ability;<br>2. High deployment cost;<br>3. Low security levels (Tags are easy to be cracked);<br>4. Hard to manage;<br>5. High maintenance fee |
| Ultrasonic Sensing | 1. Easy to be influenced by other high-frequency noise;<br>2. High cost, especially in outdoor parking-lot;<br>3. The direction of receivers (antennas) need to be extremely accurate, which is inconvenient for deployment |
| Electromagnetic Induction Coil | 1. Need to be buried into the ground, high cost;<br>2. The coil are easily broken;<br>3. High maintenance cost;<br>4. Easy to be disturbed;<br>5. Short lifetime of coil leads to the decrease of accuracy |

stops, the curve becomes flat and the magnetic value changes again until the car leaves.

Also, we can see that in Fig. 3(1) & Fig. 3(2) and Fig. 3(3) & Fig. 3(4), the initial magnetic value of the same axis is different, although the sensor is placed in the same environment. This is because the magnetic sensors are too sensitive. The data value exhibits large changes in response to very small variations of a sensor's laying angles or a vehicle's parking angles. Therefore, in this paper an innovative algorithm, called the Background Difference Detecting Algorithm based on Environment Learning (BDDAEL), is proposed to solve this problem. By environment learning, this problem can be effectively managed without affecting the detection accuracy.

### *B. BDDAEL Algorithm*

When a sensor is placed in the center of the parking space, it immediately starts to learn the environment after initializing the status to "vacant". The environment learning is shown in Fig. 4(a).

Firstly, the system starts sampling for 10 seconds with sampling rate 1 Hz. Ten sets of data, which include 3-axis geomagnetic values, are collected after 10 seconds. The mathematical description of our algorithm is shown in the following steps:

**Step 1:** Collect 3-axis data for 10 seconds at a 1 Hz sampling rate. Assuming $\lambda_i = \{X_i, Y_i, Z_i\}$, where $i$ is the sampling index, $X_i$, $Y_i$, $Z_i$ represent the 3-axis values, $\lambda_i$ is the data set collected in the $i^{th}$ sec.

**Step 2:** Compare the values of each axis.

$$\Delta\lambda_k = \{|\lambda_{k+1} - \lambda_k|\}, k \in [1, 9]_{integer} \tag{1}$$

where $\{|\lambda_{k+1} - \lambda_k|\} = Max\{|X_{k+1} - X_k|, |Y_{k+1} - Y_k|, |Z_{k+1} - Z_k|\}$ and $\Delta\lambda$ includes all the comparisons of any 2 adjacent sample values, $k \in [1, 9]_{integer}$. Assume $\lambda_{thd}$ is the pre-defined threshold value. If all values in $\Delta\lambda < \lambda_{thd}$, then the environment is declared steady and the system goes to Step 3. Otherwise, the environment is declared unsteady, the system returns to Step 1, and another 10 seconds of sampling ensues.

**Step 3:** Find the reference geomagnetic field value.

$$\lambda_{ref} = \{\frac{\sum_{i=1}^{10} X_i}{10}, \frac{\sum_{i=1}^{10} Y_i}{10}, \frac{\sum_{i=1}^{10} Z_i}{10}\} \tag{2}$$

Through this environment learning method, problems mentioned in previous section can be effectively managed without affecting the detection accuracy.

**Step 4:** Compare the current sampling value $\lambda_{crt}$ to the $\lambda_{ref}$.

The flow chart is shown in Fig. 4(b).

After finishing environment learning, the system samples the geomagnetic data in real time. In order to increase sampling accuracy, a moving average filter algorithm is used. In this filter algorithm, five successively sampled data form a subset. The first data in moving average is acquired by calculating the average value of the initial five sampled data. Then the first number of the series is excluded and simultaneously the next number is added into this subset, in which the averaged value is updated and regarded as the current geomagnetic data. Comparing the current sampling value $\lambda_{crt}$ to the $\lambda_{ref}$, that is $\Delta g = Max|\lambda_{crt} - \lambda_{ref}| = Max\{|\lambda_{crtX} - \lambda_{refX}|, |\lambda_{crtY} - \lambda_{refY}|, |\lambda_{crtZ} - \lambda_{refZ}|\}$. Assume $G_{sst}$ is the trigger threshold and $G_{sst} = \{G_{sstX}, G_{sstY}, G_{sstZ}\}$. The value of $G_{sst}$ will change according to different environments.

Generally, $G_{sst}$ is within a range and can be approximately determined by several initializations (in our experiment the $G_{sst}$ is 20 for each axis). The sensitivity of the entire system can be controlled by setting a different trigger threshold for each axis. In our algorithms, the "occupied" status is determined by only 3 successive comparisons $\Delta g$ which are all larger than $G_{sst}$. Otherwise, the system determines that the geomagnetic field value changes due to some burst interference, and the parking status should be "vacant".

### *C. Background Data Updating*

In BDDAEL algorithm, detecting parking space status is primarily dependent upon the background data obtained via environment learning. With time and temperature changes

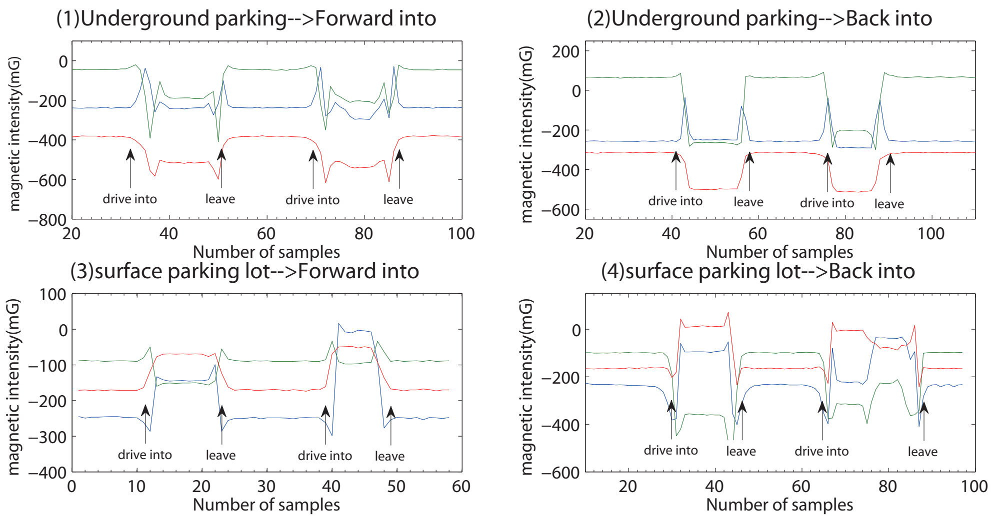



Fig. 3. Magnetoresistive Sensor Data Curves. The blue, red and green lines stand for $x$-axis, $y$-axis and $z$-axis, respectively.

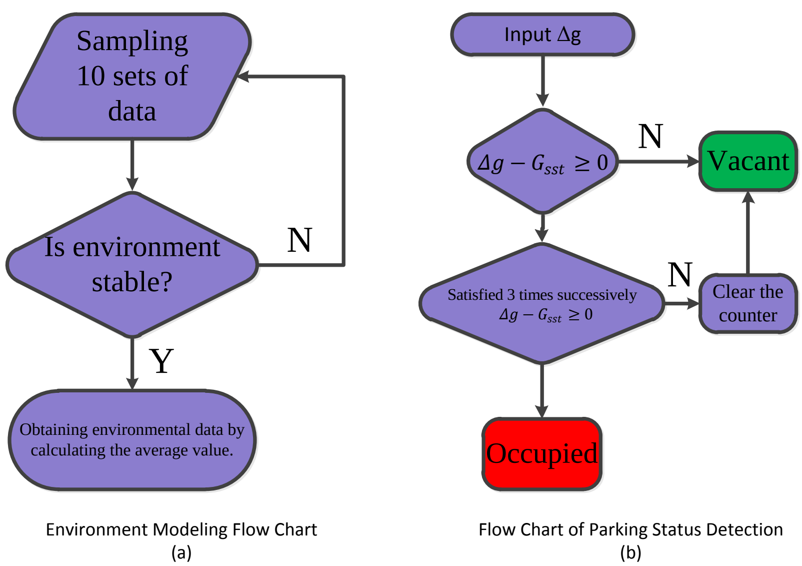



Fig. 4. Environment Modeling Flow Chart and Parking Status Detection Flow Chart.

the geomagnetic field might vary in the detection area. If background data is not updated in time, the entire algorithm might fail due to the accumulated variations. Therefore, it is necessary to set an appropriate background data updating mechanism. In our algorithm, two methods are proposed to update background data in time. The first one is to update background data manually. This method can be realized by manual input in corresponding software; another method is an automatic mechanism accomplished by the sensors themselves. When the system determines that a parking space has been vacant after a period of time $T_{update}$, which implies a steady environment, the system goes to Step 1 mentioned in the previous section to restart the environment learning.

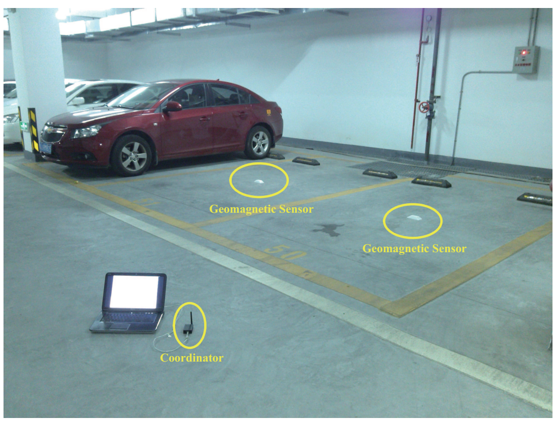
## V. Results Analysis

In order to test the accuracy of our BDDAEL algorithm, we conducted our field experiment and recorded the data from four different parking lots under different environments. We chose two underground parking lots and two overground parking lots and we implemented 60 tests (means we tested 60 cars moving in and out) at each parking lot. Fig. $5(a)$ shows one of the parking lots in which the field experiments were performed.

Fig. $5(b)$ shows the results of all four field experiment. On all four parking lots, the accuracy rate remains in a high level of over $96\%$.

For robustness test, consider the characteristics of the magnetoresistive sensors, we designed a scenario that people carrying metal objects walks in and out of a parking space. In our BDDAEL algorithm, the sensitivity of the entire system can be determined by setting the trigger threshold $G_{sst}$, which is a convertible parameter according to different environments.

If we set the trigger threshold $G_{sst}$ at an appropriate value, such man-made interference can be neglected by the system itself. In our experiment, $G_{sst}$ is set to 20 (in most case $G_{sst}$ is within a range). In this configuration, when people carrying metal objects walk into and out of a parking space, the system is undisturbed and stays in stable. The system has high robustness.




(a) Field Experiment

TABLE I
PARKING DETECTION INFORMATION IN REAL TIME

| Parking Lots | Number of Parking Space | NO.of Test | Time of Accuracy | Accuracy Rate |
|---|---|---|---|---|
| Underground1 | 57 | 60 | 60 | 100% |
| Underground2 | 62 | 60 | 59 | 98.30% |
| Overground1 | 7 | 60 | 60 | 100% |
| Overground2 | 9 | 60 | 58 | 96.70% |

(b) Parking Detection Results

Fig. 5. Field Experiment Scene and Parking Detection Results in Real Time.

## VI. CONCLUSION

Wireless sensor networks technology effectively provides an economic and convenient method for parking space detection systems. In this paper, geomagnetic sensors are utilized to detect the parking status. Also, an innovative BDDAEL algorithm, based on environment learning, energy conservation, detection accuracy and background data updating, is presented to solve some common problems existing in other parking space detection schemes. The results show that our system has high scalability, perfect accuracy, long lifetime, and low susceptibility properties, which is advanced compared to other existing parking space detection system. In future work, how to further reducing the energy consumption will be a key study item. Moreover, how to appropriately place the router in the parking lot needs to be further studied.

## VII. ACKNOWLEDGMENT

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