Beacon Proximity Based Service to Find Nearby Parking Spaces

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***Abstract*—The Internet of Things (IoT) is often embedded as a crucial part of many smart systems, especially in car park recommendation systems. Such recommendations require the knowledge of the current location of the car driver through a mobile application, yet existing mobile sensors such as GPS and Barometer sensor are not significantly qualified or stabilized to deliver a current location. Therefore, this research proposes using an installed IoT location based service, named Beacon, to act as a proximity sensor to transmit current car locations to recommend nearby parking spaces to the driver via a mobile application. The proposed system is explained in detail and implemented to test its accuracy. In the experiment, the accuracy of nearby parking space recommendations was assessed and compared with previous studies.**

***Index Terms*—Finding nearby parking zones, mobile parking, parking space recommendation, Beacon technology, internet of things**

I. Introduction

The number of cars in urban areas has increased dramatically in line with rapid economic growth. Demand for parking space construction or facilities is growing and of great prominence. Car parking systems are determined to be facilities which facilitate public parking.

Car parking system has continuously evolved in a wide variety of forms and varies between infrastructure and the system itself. This stimulates the effort of researchers to further develop car parking systems using continuously developing technologies. In the research community, an approaching car parking system has been proposed as a solution rather than a system alone. The integration of collaborative parts, including infrastructure, sensors, the system platform, and functions should be designed carefully [1], [2].

For infrastructure in the Internet of Things (IoT) era, accessing parking systems can be done through a wide variety of networks, such as wireless sensor network (WSN or WiFi) [3] and Zigbee [4], as well as sensors such as radio frequency identification (RFID) [4], [5], Near Field Communication (NFC) [6], and infrared sensors [7]-[9]. Installing an appropriate network which co-operates with a suitable sensor can support the system's capability, especially for mobile platforms.

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Generally, drivers can access the mobile application through various options, such as global system for mobile network (GSM), WiFi, and Bluetooth which are provided by the device. Moreover, many useful sensors such as GPS, NFC, and Barometer sensor can be enabled when the application requires it. Due to these facilities, a mobile application can be developed so that it is not merely limited to only operational functions. One an interesting function studied by the research community is finding parking spaces for drivers.

There are many studies that can recommend suitable parking spaces for drivers. The first study in this area was to find the nearest parking space using the support of a mobile phone's GPS [1], [2]. Unfortunately, GPS signal cannot work well in indoor environments, so if a car park is in a building the signal can be insufficient.

Other efforts to find parking spaces can be through considering suitable parking spaces based on the user's profile [10] and user preference [11]. These considerations will work reasonably well when users willingly provide as much information as possible. In the initial stage or in instances where there is blank data, these recommendations must recommend according to proximity.

Interestingly, the first study to find a parking space has been used as a basic option in many later studies. Moreover, IoT is currently recognized to be an assistance in building a smart car parking [12]-[15]. In recent years, barometer sensor has been proposed to determine the current floor that the car is on to support recommendation functionality [16]. Nearby parking spaces on the current floor will be offered to the driver upon driving to each floor. Although barometer sensor can be enabled in the car park buildings, in practice the values produced are unstable during determining the correct floor.

Therefore, this research attempts to find an appropriate sensor which can support the search for nearby parking spaces and recommend them to users to overcome those problems. The Beacon sensor is proposed in the present study in place of using GPS or a barometer sensor.

Finally, this research proposes adopting a Beacon sensor, a proximity sensor, to provide a location-based service to a mobile application to find nearby parking spaces to drivers. The adoption of Beacon sensor integrated with the mobile car parking application is discussed in terms of how well they work together.

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The implementation of the mobile parking application and Beacon sensor installment based on the floor plan was conducted in an experiment to monitor the accuracy between the proposed solutions with previous studies to ensure acceptable performance.

II. System Architecture Review

The system architecture of a car park system which provides parking space recommendations through a mobile application typically consists of three main functions, as shown in Fig. 1.

A. *Toolgate Registering*

The automated car parking system initially sets up a kiosk to distribute a radio frequency identification (RFID) card to the driver for registration. Since mobile devices now typically have NFC installed for near communication usage, it is suitable for registration and avoids extra costs and time. Similar to previous studies [10], [11], [16], the present study implements a mobile car parking application which includes a registration at either the entry or exit using NFC tapping at a kiosk.

B. *Finding Parking Spaces*

Many functions have been proposed to find nearby parking spaces for drivers, including breadth-first search [1] and Dijkstra shortest path [5]. Nevertheless, these functions require a powerful GPS signal in an indoor environment.

Recently, a periodical recommendation [16] adopted Barometer sensor of a mobile device to detect the current floor to recommend the nearest parking space to the driver. Although standing on the first floor, Barometer sensor detected values of 28.48m and 28.28m, as shown in Fig. 2.

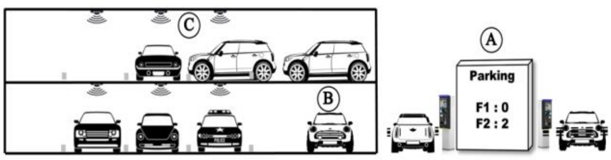


Fig. 1. Three main functions of a car parking system.

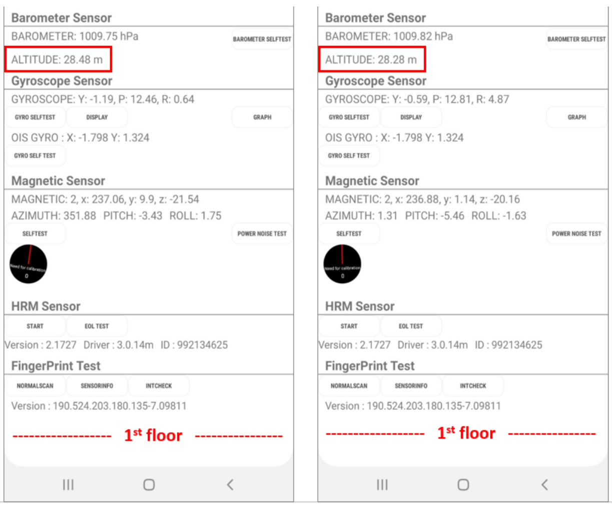


Fig. 2. Two altitudes obtained from Barometer sensor on the 1st floor.

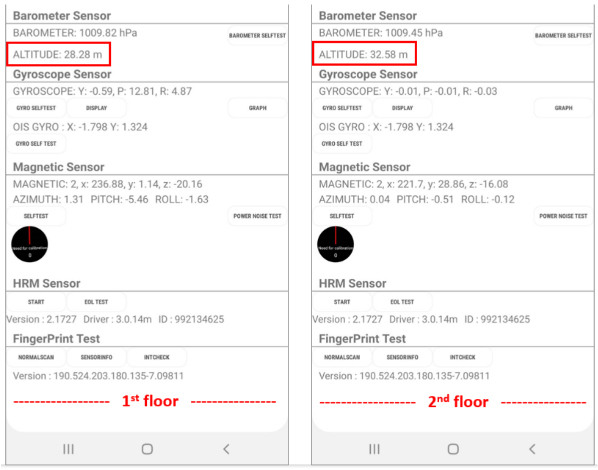


Fig. 3. Two altitudes obtained from Barometer sensor on the 1st and 2nd floors.

Meanwhile, Fig. 3 shows that Barometer sensor values range between 28.28m and 32.58m for the first and second floors, respectively. Due to the inconsistent altitude values, real-time floor determination is unreliable and is rarely implemented.

However, finding nearby parking space is considered necessary and is a pivot function in many research studies [10]-[16], and adopting an appropriate sensor network to help find parking spaces can improve the overall accuracy of parking space recommendations.

C. *Reporting Slot Occupancy*

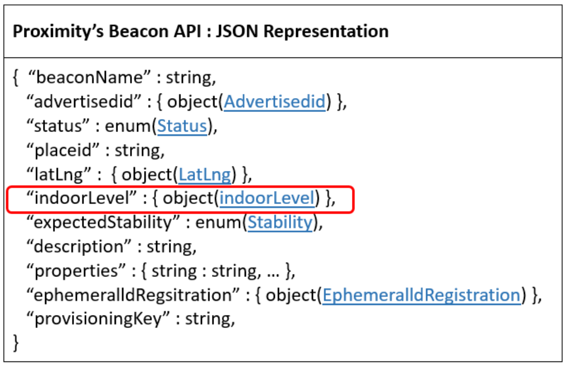
Nowadays, unoccupied parking spaces can be reported to drivers using a board at the entrance of the car park or on every floor. In this study, a mobile application is responsible for reporting all information to the driver directly.

III. Proposed Solution

Apple Inc. initiated Beacon technology to cooperate with mobile application development in 2013. It is recommended that Beacon technology is installed indoors or in areas that GPS signal cannot cover. Beacon is compatible with iOS version 7.1 onward, and Android version 4.3 onward. It has already been adopted in various domains, including small business marketing and tracking, personal gadgets, and the Internet of Things (IoT).

For the IoT, Beacon acts as a proximity sensor which repeatedly transmits a single signal that Bluetooth-equipped devices like mobile phones can detect when they are within its 70m range. Beacon broadcasts a package, including its identification and proximity value transmitted on a regular interval of approximately 1/10th per second. The mobile application will receive the package obtained from Beacon's broadcasting via Google application program interfaces (Google APIs) and is represented as a JSON format in Fig. 4.

Referring to the indoor level shown in Fig. 4, this is a human-readable string which indicates which floor the Beacon is located. Once a mobile device receives a broadcasted package, it can determine the current floor for use in the recommendation.



Proximity's Beacon API : JSON Representation


```
{ "beaconName" : string,
  "advertisedid" : { object(Advertisedid) },
  "status" : enum(Status),
  "placeid" : string,
  "latLng" : { object(LatLng) },
  "indoorLevel" : { object(indoorLevel) },
  "expectedStability" : enum(Stability),
  "description" : string,
  "properties" : { string : string, ... },
  "ephemeralIdRegsitration" : { object(EphemeralIdRegistration) },
  "provisioningKey" : string,
}
```


Fig. 4. Proximity's Beacon API in JSON format.

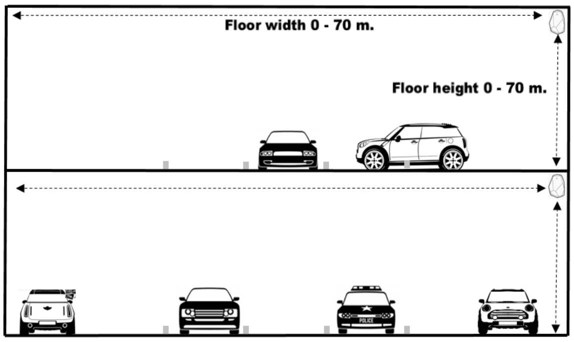


Fig. 5. Beacon sensor installment.

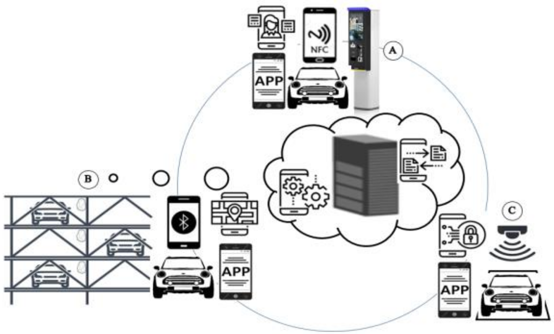


Fig. 6. IoT-Beacon mobile car parking system.

A crucial part of adopting Beacon sensor is its installation according to a particular floor plan. Beacon sensor work well in broad areas without concrete or metal barriers. If there are many barriers, more Beacon sensors are required with the area divided into sub-areas and where the area is larger than 70 square meters. Since the recommendation requires determining the floor where the driver is, while the parking floor plan is wide and separated by concrete floors, each floor should install at least one by default, as shown in Fig. 5.

Referring to Fig. 6, three functions of the proposed system will be discussed in detail to illustrate how a nearby parking space can be delivered to the driver.

A. NFC Tapping for Registeration

First, the system requests the driver to register via a mobile application. The requested information is not limited only to the car's license number, as with traditional systems, but also the user's profile, while their privileges and preferences are optionally requested to support the recommendations, as shown in Fig. 7.

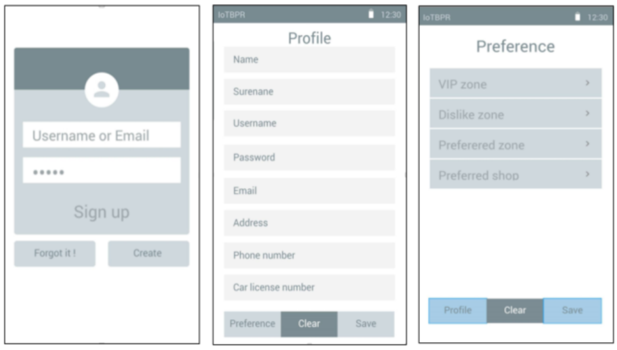


Fig. 7. Driver registration.

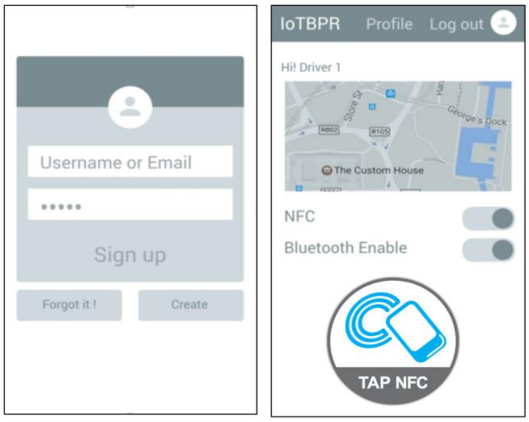


Fig. 8. Sign in and check in.

The application will enable mobile NFC, allowing the driver to tap their mobile at a tollgate kiosk to check in. Since NFC check in is a peer-to-peer communication, the system can ensure that it securely verifies single-access system to automatically know who is accessing it. However, the driver must sign-in to the application before reaching a tollgate, as shown in Fig. 8.

B. Beacon Detecting for Nearby Zone Recommendation

After the registration is complete, the application will recommend a nearby parking space that mostly matched to three considerations. First, the user's profile can identify their disliked zones and those reserved for members or VIPs (privilege zones). The entire zones which are reserved as VIP zones as well as those that are disliked should be firstly filtered from the recommended list. The second consideration is the user preference which will then be determined in detail based on the user's preferred zones or zones that are nearby shopping stores. Finally, entire zones which matched to user's profile and preference will determine whether they are nearby zones or not. Detecting a broadcast package from a Beacon sensor delivers the current floor where the car is as well as all registered zones. Zones that are also nearby to a car's driver will be finally recommended to a car driver. Three criteria used in the recommendation is summarized in Fig. 9.

The function used to compute the similarity between a nearby zone (Z_i) and the car's driver or user (U) are defined as

$$\text{Similarity}(U, Z_i) = e^{-\text{distance}(U, Z_i)} \quad (1)$$

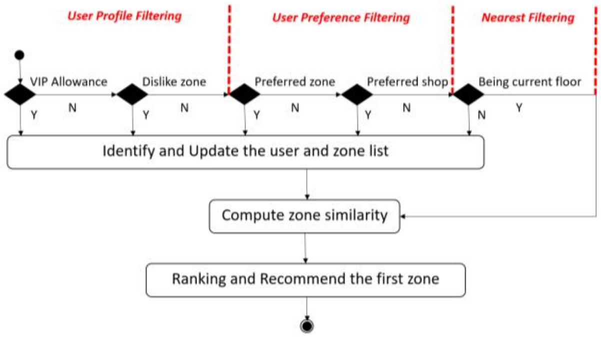


Fig. 9. Conditions used to find a parking space.

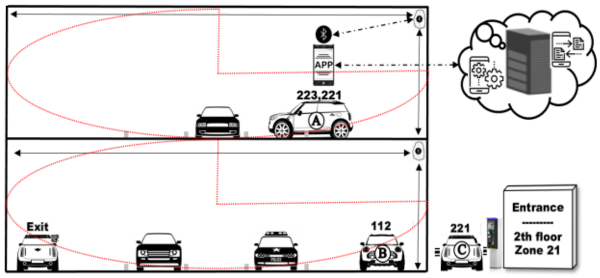


Fig. 10. Beacon sensor installment.

The distance between each parking zone (Z_i) and a user (U) is evaluated according to whether or not it is a preferred zone, defined as

$$\text{distance}(U, Z_i) = | z_i - u | \quad (2)$$

If a nearby zone Z_i is the preferred zone, the value "u" is as "1", otherwise it is "0". This value can be retrieved from the registered information as shown in Fig. 6. While is located at a floor, the mobile application will receive a broadcast package form a nearby Beacon sensor installed in that area. The indoor level determines the current floor that the user is at and the Beacon ID can be used to identify entire nearby zones which are in a 70m range.

Fig. 10 shows that the user (car driver "A") can see the list of nearby parking zones within a 70m area, sorted by zone preference, and registered with Beacon "2" installed on the second floor. Each driver can only see the preference zones that are nearby on a particular floor. Since the first floor has already been recommended to the driver "B", a nearby and preference zone in the next floor is recommended to a new driver "C", instead.

Due to Beacon's limited 70m range, excluding steel and concrete barriers, the coverage of an installed Beacon sensor should be considered according to the floor plan and size to enhance the recommendation accuracy. Suppose that if a floor plan is too large, two Beacon sensors are installed on a floor as shown in Fig. 11.

The given car park is a four-floor building, consisting of two entry gates and one exit gate in the middle. When a driver drives to the second floor from the left side, the mobile will detect and receive a package from Beacon 3, as shown in Fig. 12.

All related zones registered with Beacon 3 will be retrieved to compute the similarities before recommending a space to the driver, as summarized in Fig. 13.

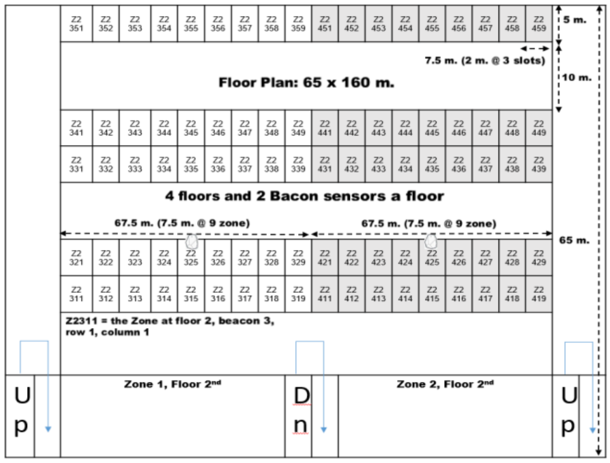


Fig. 11. Two Beacon sensors installation.

	Received package		User Preference	User Profile	
User	Indoor Level	Beacon Id	Prefered zone	Dislike	Disallow
U	2	3	Z1151, Z2311, Z2451	Z2312, Z2411	Z2351, Z2451

Fig. 12. Two Beacon sensors installation on the second floor.

Registered zone of Beacon i			User Preference	User Profile					
Zone	Floor	Beacon Id	Prefered zone	Dislike	Disallow	Distance(U,Zi)		Similary(U, Zi) %	Ranking
Z2311	2	3	1			0.00	|1-1|	100	1
~~Z2312~~	~~2~~	~~3~~		~~1~~					
...									
Z2321	2	3				1.00	|1-0|	36.79	2
Z2322	2	3				1.00	|1-0|	36.79	2
...									
~~Z2351~~	~~2~~	~~3~~	~~1~~		~~1~~				
~~Z2352~~					~~1~~				

Fig. 13. Similarity computation of nearby zones under Beacon 3.

While driving in the area where Beacon 4 broadcasts a package, the similarity computation of the entire zone registered with Beacon 4 will be done in sequence. Therefore, nearby parking zones can be delivered to a driver while driving to different zones and floors. Finding nearby zones will be automatically updated based on which Beacon is responsible and within each Beacon's 70m range.

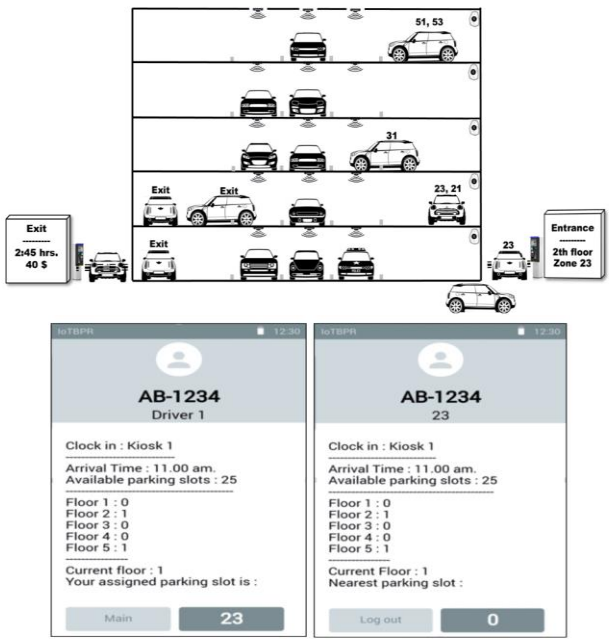


Fig. 14. Reporting a recommended nearby parking zone.

C. Mobile Application Reporting

The mobile application is implemented to allow communication with a cloud server to retrieve all information about the parking zone and spaces, the user's profile and preferences, and all related sensors. The results obtained from the NFC detection and Beacon sensor are required to process the server and report to the driver.

Reporting all available parking zones (or spaces) and recommending a nearby zone while driving is used to facilitate drivers to park their car, as shown in Fig. 14.

IV. Experiment and Evaluation

An experiment was designed and set up to confirm that adopting the Beacon sensor can improve the accuracy of searching for nearby parking zones or spaces.

A floor plan of a department store in Bangkok was simulated as a test case whose size is shown in Fig. 11. A total of eight Beacon sensors were installed in the four-floor car park building, with the Beacon sensors registered to all the parking zones.

Five testers were used to generate 100 test cases. First, they were requested to register and identify their profiles and preferences via a mobile application before recording their outcomes. All test cases were randomly generated to cover four possible periods, including normal as well as busy weekday and weekend periods. The outcomes are classified according to the defined matrix in Table I. The three related recommendations from [10], [11], and [16] were also implemented to test their accuracy in relation to the proposed recommendation. The accuracy is defined as:

$$\text{Accuracy} = \frac{\text{TP+TN}}{\text{TP+TN+FP+FN}} \quad (3)$$

The actual parking obtained by recommendation (TP) and none of recommendation (TN) will be evaluated from entire cases – including TP, TN, parking ignorance in both recommendation (FP) as well as without any recommendation (FN). They can be represented in term of recommendation matrix in Table I.

The comparative studies concerned in this experiment are re-named in Table II.

TABLE I: RECOMMENDATION MATRIX

Actual Park	Nearby Parking Zone	
	Recommended (Positive)	Not Recommended (Negative)
Park (True)	True Positive (TP)	True Negative (TN)
Not Park (False)	False Positive (FP)	False Negative (FN)

TABLE II: COMPARATIVE STUDIES

No	Code	Description
1	UR	User profile recommendation [10]
2	CR	User profile and preference recommendation [11]
3	PR	Barometer sensor - periodical recommendation [16]
4	NR	Beacon sensor – Nearby recommendation

TABLE III: OUTCOME OF TEST CASES

Code	True positive (TP)	True negative (TN)	False positive (FP)	False negative (FN)
UR	23	22	20	35
CR	41	20	19	20
PR	50	18	12	20
NR	55	18	12	15

TABLE IV: ACCURACY AND F-MEASURE COMPARISON

Code	Accuracy (TP+TN)/N	Recall (R) TP/(TP+FP)	Precision (P) TP/(TP+FN)	F-Measure 2PR/(R+P)
UR	0.45	0.53	0.40	0.46
CR	0.61	0.68	0.67	0.68
PR	0.68	0.81	0.71	0.76
NR	0.73	0.82	0.79	0.80

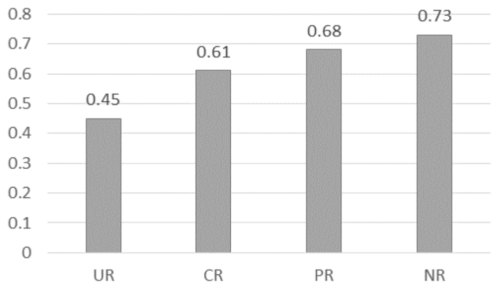


Fig. 15. Accuracy comparison.

The outcomes of recommending a nearby parking zone were recorded based on the matrix defined in Table I. This illustrates how many times the recommendation matched the actual parking spaces (true positive) and no parking spaces (false positive), as well as not matched to actual parking spaces (true negative) and no parking spaces (false negative), as summarized in Table III.

The accuracy and other corresponding measures including recall, precision, and simplified recall, as well as precision in terms of F-measure were then calculated and shown in Table IV.

Referring to Fig. 15, the result of the accuracy comparison shows that the accuracy of the proposed recommendation when finding a nearby parking zone (NR) was highest at 0.73 compared to the previous recommendations "UR" (0.45), "CR" (0.61) and "PR" (0.68). In fact, the proposed recommendation included pivot criteria used in previous works, including User Profile (UR), and user profile and preference (CR) in its recommendation. Therefore, its accuracy should be equal to the CR at a minimum.

The recommendation accuracies of "PR" (0.68) and "NR" (0.73) are higher than the "UR" and "PR" recommendations. This shows that recommending nearby zones can improve recommendation accuracy. If a car driver prefers to park in a nearby zone, the nearby zone is the significant criteria used to make recommendations to the driver and is required by various studies. In addition, considering both the user profile and preference with the nearby criteria can improve the recommendation's performance.

Since Beacon sensors broadcast a package containing the indoor level and identification number, rather than just altitude like Barometer sensor, the mobile application can accurately retrieve the corresponding the floor and nearby zone. Detecting the unstable altitude value of a Barometer sensor requires an application to validate the correct floor several times.

Both "PR" and "NR" require an effective sensor to provide precise data about the current floor or nearby zones used in the recommendation. The accuracy of proposed recommendation "NR" (0.73) is higher than "PR" (0.68), although not by a large margin. This may be due to the small number of test cases, since a free parking space could be found suddenly but not be recommended.

Finally, the maximum accuracy of recommendations is 70 percent, which has not yet been satisfied and must improve in the future. Finding a nearby parking space supported by Beacon sensors as well as the user's profile preferred parking zones are used to justify the user's needs. Installation of suitable infrastructure and sensors able to cooperate with an appropriate recommendation can improve accuracy.

V. Conclusion

Since GPS signals are unstable within indoor environments, they are unsuitable for use in finding indoor parking spaces. Various studies have attempted to overcome this difficulty. In recent years, the Internet of Things (IoT) is the most commonly used to facilitate parking space recommendations.

Car parking systems provide a mobile application to recommend suitable parking spaces to car drivers, but they require appropriate sensors and a network. Providing a better network and sensor installation can improve the accuracy of recommendations for nearby parking spaces.

This study therefore proposed adopting Beacon sensors to support the search for nearby parking spaces or zones to resolve GPS signal lost and serve the driver needs.

Beacon sensors are installed to cover a specific area, while the mobile application is used to detect the Bluetooth Beacon signal, extract the current floor from the indoor level and nearby zones from Beacon ID stored in a broadcasted package, and deliver nearby zones to the driver.

An experiment was devised to test the accuracy of the nearby zone recommendations to drivers. The result shows that it is most accurate when compared to previous studies. The experiment found that the recommendation accuracy—focusing only on the user profile and preference—decreased if the user's profile and preferences were not identified. Therefore, considering the user's localization can be an effective criterion for the recommendations. In addition, if the user's current location can be determined accurately and precisely, the recommendation accuracy also increases.

However, further improvement to infrastructure such as the network and sensors, as well as the criteria used to construct effective recommendations is required. Moreover, it would be better if the obstacles and limitations encountered in this research are studied further.

Since there are no test cases provided, the testing required setting up an experiment which could not be fully installed. Installing in real situations is required for greater accuracy.

Next, finding the nearest parking space or zone within this system requires detecting the current floor and nearby zones within a 70 m area. Therefore, the installation of the Beacon sensors is a pivotal task. If the layout or floor plan is too large or contains a lot of steel or concrete barriers, more Beacon sensors are required in the proper position. Installing Beacon sensors may decrease the accuracy of the recommendations if it insufficiently covers or fails to cover all the parking zones. However, handling multiple Beacon sensors on the same floor requires further study.

As technology continues to evolve, it is strongly recommended that efforts are made to develop better infrastructure, sensors, and system functions to support users to effectively find parking spaces. Furthermore, since certain adopted technologies are continuously updated, monitoring is required to continue improving systems reliant upon them.

Conflict of Interest

The study authors declare no conflicts of interest.

Author Contributions

The first author conducted the research and experiment, analyzed the data, and wrote the paper. The second author was responsible for proofreading and revised the final version of the paper. All authors have approved the final version.

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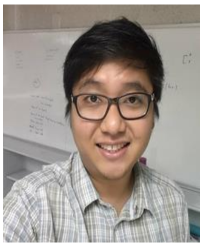

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