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A Recommendation Model of Smart Parking

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***Abstract*—Parking search is a challenging task in most urban areas. The traffic resulting from drivers cruising for parking has a great effect on the environment, increasing energy consumption and emissions of CO2. Existing parking search applications only provide the information such as the address of parking spot, turn-by-turn navigation to the parking destination and available parking space. We have proposed a real-time parking android-based APP for Pingtung city, which connects with different parking management servers to locate the best parking spaces based on the drivers needs, such as driving distance to parking spot, walking distance from parking spot to destination, available parking space and parking price. The results have shown that the APP helps to reduce the environmental burden as well as the time spent looking for parking.**

***Index Terms*—Android-based APP, Pingtung, Parking**

I. INTRODUCTION

Currently much effort has been concentrated on Intelligent Transport System (ITS) research. Parking Guidance and Information System (PGIS) has been developed as a solution and service of ITS in urban environment. PGIS helps driver aware of the available parking space of his surroundings and provides the guidance to possible destination, thus leading to a reduction of time spent searching for parking spots favorable for driver. Many methods regarding PGIS have been proposed to assist drivers to achieve an efficient way for parking in a congested city. We may categorize them into two main approaches: hardware-based [1-5] and infrastructure-based [6-11]. Hardware-based approach can be further divided into two types: sensor-based [1-3] and marking-based [4-5]. With deploying various ranging-sensing sensor on both sides of vehicle, the space detection of sensor-based [1-3] specifies a target position by recognizing available parking space between two adjacent vehicles. Rather than needs the presence of neighboring vehicles, marking-based [4-5] requires existing vehicles mounted cameras as a detection tool. Parking slot marking can be acknowledged through some image processing algorithm. Unlike the above mentioned approaches, infrastructure-based [6-11] locates and reserves the desired parking position by integrating services and communication between vehicle and infrastructure.

In this paper, we have proposed a recommendation system of smart parking and developed an android-based mobile APP that assists the driver to find the suitable parking spots in Pingtung city based on his preference. The driver uses the APP to interact with the server and receive the recommended option parking list. The proposed system integrates target guidance and vacant tracking. The driver can access to analytics platform on the server to find out the use of the facilities of related parking spots.

The rest of this paper is organized as follows. Section 2 describes the proposed model. Section 3 presents the experiment and result. Finally, we conclude in section 4.

II. THE PROPOSED SYSTEM

Suppose we have four factors affecting the choice of parking spot, which are described as follows.

- Walking distance (L): the distance (meters) from parking spot to destination. Usually driver chooses the shorter walking distance.
- Driving distance (D): the distance (meters) from current position to some parking spot, which is calculated by Google map. Driver prefers to the route of short driving distance.
- Available parking spaces (E): number of current available parking spaces in a parking zone, which are monitored and updated periodically by server of parking center. The more the available parking spaces are, the much easier for the drivers to park there.
- Parking fees (F): parking fees are charged on hourly basis. The fewer the better.

When the driver triggers the recommendation model, the recommended status of the parking zones are needed to rank. Based on the target resource usage, multiple attribute decision making process calculates the recommendation status according to the system administrator's past experience by weighting the above four factors. The procedures can be described as follows.

Let the recommendation status is the objective. We have vector set G=$\{L, D, E, F\}$ with corresponding the attributes name of row vector (Table 1) and the available parking zones with corresponding the attribute name of column vector (Table 2). The recommendation status makes up the decision scheme set P=$\{P_1, P_2, ..., P_n\}$, and the attribute values of recommendation status of P_i is $\{Y_{i_1}, Y_{i_2}, Y_{i_3}, Y_{i_4}\}$ of which Y_{i_1}=L_{P_i}, Y_{i_2}=D_{P_i}, Y_{i_3}=E_{P_i}, Y_{i_4}=F_{P_i} (i=1, 2, ..., n). We take P=$\{P_1, P_2, ..., P_n\}$ as the decision scheme set and G=$\{L, D, E, F\}$ as the destination vector set. We establish the decision matrix $\mathbf{A}$= $(a_{ij})_{n\times 4}$ and normalize the decision making matrix $\mathbf{A}$= $(a_{ij})_{n\times 4}$ as (1) and (2) to obtain a standardized matrix

TABLE I
ATTRIBUTE NAME OF ROW VECTOR IN MATRIX $\mathbf{A}$

j	1	2	3	4
Attribute	L	D	E	F

TABLE II
ATTRIBUTE NAME OF COLUMN VECTOR IN MATRIX $\mathbf{A}$

i	**Parking Zone**
1	PERFORMING ARTS CENTER
2	GUI-LIN street
3	XIN-YI road
4	WAN-CHANG street
5	THE PACIFICS
6	ZHONG-HUA road
7	GUANG-FU road
8	GREEN LIFE

R= $(r_{ij})_{n\times 4}$, where I_1 and I_2 represents the benefit and cost index set, respectively. Please note $E \subseteq I_1$ and $L, D, F \subseteq I_2$.

$$r_{ij} = \frac{a_{ij}}{max(a_{ij})}, i \in \{1, 2, ..., n\}, j \in I_1 \tag{1}$$

$$r_{ij} = \frac{min(a_{ij})}{a_{ij}}, i \in \{1, 2, ..., n\}, j \in I_2 \tag{2}$$

Let w_1, w_2, w_3 and w_4 indicate the weighting factor of L, D, E and F, respectively. We have the index weight vector W=(w_1, w_2, w_3, w_4), where W=w_1+w_2+w_3+w_4=1. Let **K**= $(k_{ij})_{n\times 4}$, where k_{ij} = $r_{ij}\times w_j$, j=1, 2, 3, 4. We have the comprehensive attribute values $Z_i(W)$=$\sum_{j=1}^{4} k_{ij}$. Finally, we rank the comprehensive attribute values $Z_i(W)$ to get the solution. The greater the comprehensive attribute value is, the higher the recommended status is.

III. EXPERIMENTS AND EVALUATION

Fig.1 has shown the flowchart of recommendation system. The mobile APP first connects MYSQL database via WiFi or 4G signal to retrieve the related parking zone data. For the sake of speedy processing, the mobile APP writes the related parking zone data into its embedded database engine SQLite. If the driver input his/her preference weighting W=(w_1, w_2, w_3, w_4), the system will display the recommended parking zone. Otherwise, the nearby parking zones will be displayed on the map. Fig.2 illustrates the system overview of parking recommendation, which consists of two parts: APP and Server. There are five modules in APP. They are parking zone information module, JSON transform module, recommendation module, list module and map module. Fig.3 depicts the sequence diagram of available parking space updated. The parking zone information module connects with parking information server, whose available parking spaces in SQLite database is periodically updated by the message from the MySQL database in parking management server. Fig.4 illustrates the sequence diagram of update between parking information server and parking management server. The parking management server, owned by parking spot merchant and controlled by parking operator, registered the cars driving in and out of the parking spot. JSON transform module converts JSON Object from 1) PHP module in parking information server, and 2) current location and destination location which contains pairs of latitude and longitude (through Geocoding API) into String and save as TEXT/VARCHAR in SQLite database. Fig.5 describes the sequence diagram of recommendation data acquisition. Recommendation module calculates the ranking parking choice based on the four factors mentioned above. APP shows the final result on map mode (Fig.6) or list mode (Fig.7) depending on the bandwidth sufficient or not.

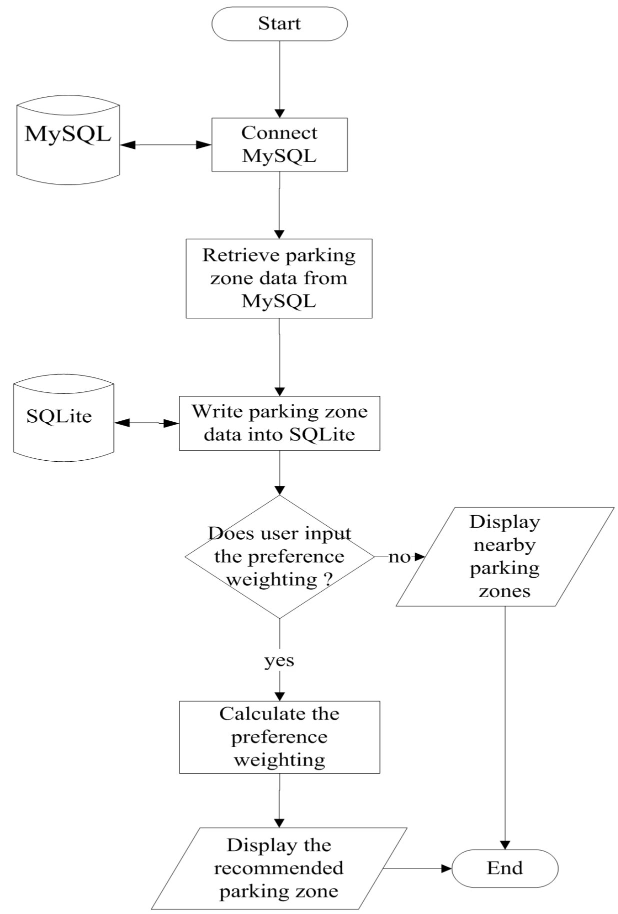

Fig. 1. Flowchart of parking recommendation

Fig.8 shows the area view of Pingtung city, on which the red dot indicates the current driver position and the big P represents the surrounding parking zones. Table 1 and 2 respectively represent the attribute name of row vector and column vector in matrix $\mathbf{A}$. Matrix $\mathbf{A}$ shows the attribute values of parking zones calculated for current driver position

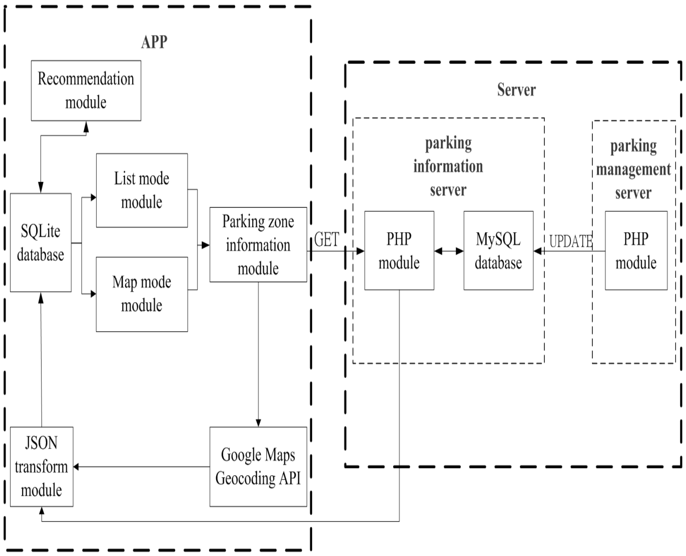

Fig. 2. System overview of parking recommendation

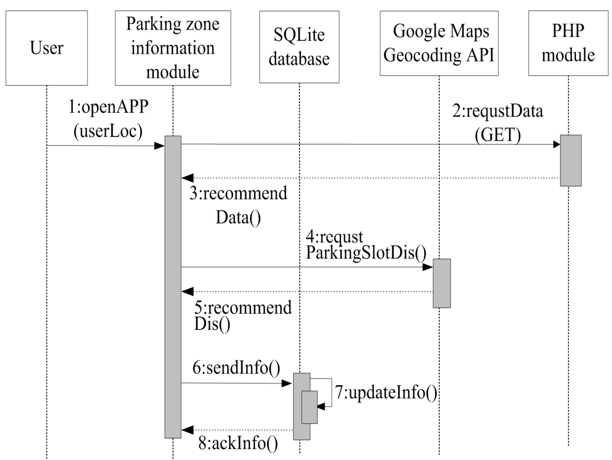

Fig. 3. Sequence diagram of available parking space updated

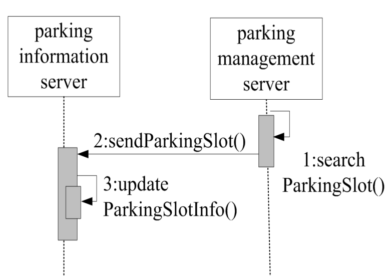

Fig. 4. Sequence diagram of update between parking information server and parking management server

based on Fig.8.

$$
\mathbf{A} = \begin{pmatrix}
225.0 & 49.2 & 25.0 & 20.0 \\
40.6 & 225.0 & 10.0 & 30.0 \\
80.6 & 234.0 & 8.0 & 30.0 \\
73.5 & 173.0 & 13.0 & 30.0 \\
71.9 & 203.0 & 25.0 & 40.0 \\
80.2 & 213.0 & 15.0 & 35.0 \\
9.1 & 236.0 & 6.0 & 50.0 \\
200.0 & 355.0 & 30.0 & 20.0
\end{pmatrix}
$$

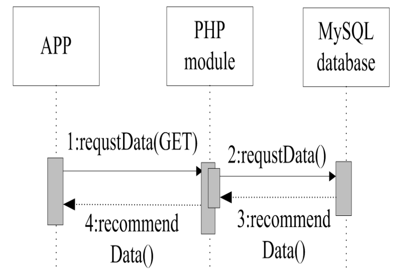

Fig. 5. Sequence diagram of recommendation data acquisition

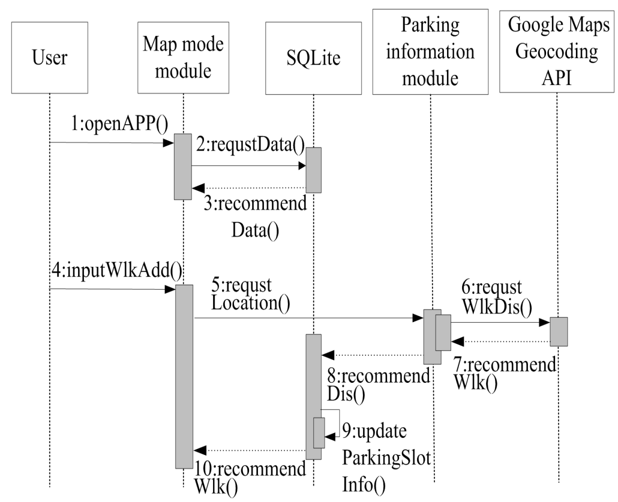

Fig. 6. Sequence diagram of map mode

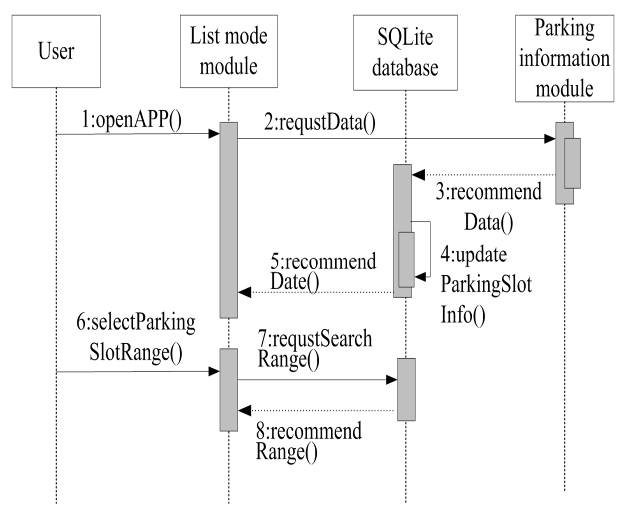

Fig. 7. Sequence diagram of list mode

As mentioned above, we know that j=3$\in I_1$, we have max(a_{i3})=30. In the same way, j=1, 2, 4$\in I_2$, we have min(a_{i1})=9.1, min(a_{i2})=49.2 and min(a_{i4})=20. We take i=1 as an instance. From equation (1) and (2), we have $r_{11} = \frac{9.1}{255.0} = 0.0357$, $r_{12} = \frac{49.2}{49.2} = 1.0000$, $r_{13} = \frac{25}{30} = 0.8333$, $r_{11} = \frac{20}{20} = 1.0000$. In the same way, we get the standard

Fig. 8. Area view of Pingtung city

matrix $\mathbf{R}=(r_{ij})_{n\times 4}$, where

$$\mathbf{R}=\begin{pmatrix} 0.0357 & 1.0000 & 0.8333 & 1.0000 \\ 0.2241 & 0.2187 & 0.3333 & 0.6667 \\ 0.1129 & 0.2103 & 0.2667 & 0.6667 \\ 0.1238 & 0.2840 & 0.4333 & 0.6667 \\ 0.1266 & 0.2424 & 0.8333 & 0.5000 \\ 0.1135 & 0.2310 & 0.5000 & 0.5714 \\ 1.0000 & 0.2085 & 0.2000 & 0.4000 \\ 0.0455 & 0.1386 & 1.0000 & 1.0000 \end{pmatrix}$$

We assume W=(w_1, w_2, w_3, w_4)=(0.25, 0.25, 0.25, 0.25). We calculate the comprehensive attribute values of recommended status according to the evaluation index weight vector W. Let $\mathbf{K}=(k_{ij})_{n\times 4}$, where $k_{ij}=r_{ij}\times w_{ij}$, j=1, 2, 3, 4. We have

$$\mathbf{K}=\begin{pmatrix} 0.0089 & 0.2500 & 0.2083 & 0.2500 \\ 0.0560 & 0.0547 & 0.0833 & 0.1667 \\ 0.0282 & 0.0526 & 0.0667 & 0.1667 \\ 0.0310 & 0.0711 & 0.1083 & 0.1667 \\ 0.0316 & 0.0606 & 0.2083 & 0.1250 \\ 0.0284 & 0.0577 & 0.1250 & 0.1429 \\ 0.2500 & 0.0521 & 0.0500 & 0.1000 \\ 0.0114 & 0.0346 & 0.2500 & 0.2500 \end{pmatrix}$$

For example, $k_{11}=r_{11}\times w_1$ = 0.0357×0.25 = 0.0089, $k_{12}=r_{12}\times w_2$ = 1.000×0.25 = 0.2500, $k_{13}=r_{13}\times w_3$ = 0.8333×0.25 = 0.2083, $k_{14}=r_{14}\times w_4$ = 1.000×0.25 = 0.2500. Thereby, we may calculate the comprehensive attribute values, $Z_1(W)=k_{11}+k_{12}+k_{13}+k_{14}$ = 0.0089+0.2500+0.2083+0.2500 = 0.7173.

Similarly, we have $Z_2(W)\sim Z_8(W)$, which are shown at Table 3. To rank the comprehensive attribute values, we need descending sorting for $Z_i(W)$, where i =1, 2, ..., 8. Finally, we have

$Z_1(W)> Z_8(W)> Z_7(W)> Z_5(W)> Z_4(W)> Z_2(W)> Z_6(W)> Z_3(W)$.

PERFORMING ARTS CENTER (i=1) is, therefore, selected as the first choice to be the parking zone (Fig.9).

TABLE III
COMPREHENSIVE ATTRIBUTE VALUES OF PARKING ZONES (W=(0.25, 0.25, 0.25, 0.25))

i	**Parking Zone**	$Z_i(W)$
1	PERFORMING ARTS CENTER	0.7173
2	GUI-LIN street	0.3607
3	XIN-YI road	0.3141
4	WAN-CHANG street	0.3771
5	THE PACIFICS	0.4256
6	ZHONG-HUA road	0.3540
7	GUANG-FU road	0.4521
8	GREEN LIFE	0.5460

TABLE IV
COMPREHENSIVE ATTRIBUTE VALUES OF PARKING ZONES (W=(0.45, 0.20, 0.20, 0.15))

i	**Parking Zone**	$Z_i(W)$
1	PERFORMING ARTS CENTER	0.5327
2	GUI-LIN street	0.3113
3	XIN-YI road	0.2462
4	WAN-CHANG street	0.2993
5	THE PACIFICS	0.3471
6	ZHONG-HUA road	0.2830
7	GUANG-FU road	0.5917
8	GREEN LIFE	0.3982

Apparently, different weighting factor have different impact for final decision. From Table 4, W=(0.45, 0.20, 0.20, 0.15) makes us to select GUANG-FU road (i=7) as preferred parking zone (Fig.10). On the other hand, W=(0.20, 0.20, 0.45, 0.15) will recommend PERFORMING ARTS CENTER (i=1) as the top choice again (Table 5). The display of recommendation result is the same as Fig.9.

IV. CONCLUSIONS

We have developed an android-based parking recommendation APP that helps drivers to find available off-street parking spaces in Pingtung city. The system has shown an option list of all possible parking spots, based on the preferences weight entered by the driver. The strength of the proposed system is that it reduces the exhaust emission caused by car cruising the street in urban environments for looking for the parking spot. Most of the drivers usually tend to choose the parking spots with vacant spaces. The proposed system update the parking information periodically, which solves the problem that the drivers find no available parking spaces upon arrival. Thus, high guidance reliability can be reserved.

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TABLE V
COMPREHENSIVE ATTRIBUTE VALUES OF PARKING ZONES (W=(0.20, 0.20, 0.45, 0.15))

i	**Parking Zone**	$Z_i(W)$
1	PERFORMING ARTS CENTER	0.7321
2	GUI-LIN street	0.3386
3	XIN-YI road	0.2846
4	WAN-CHANG street	0.3766
5	THE PACIFICS	0.5238
6	ZHONG-HUA road	0.3796
7	GUANG-FU road	0.3917
8	GREEN LIFE	0.6368

Fig. 9. Recommendation display by W=(0.25, 0.25, 0.25, 0.25) and W=(0.20, 0.20, 0.45, 0.15)

Fig. 10. Recommendation display by W=(0.45, 0.20, 0.20, 0.15)

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