Modular RFID Parking Management System based on Existed Gate System Integration

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Abstract: - In this paper, a *Modular RFID Parking Management System* that integrates the existed gate system and RFID is proposed. This system includes *Modular Gate-PC Controller and Embedded Gate Hardware, RFID System, Modular Parking Management Platform*. Most systems in *Modular RFID Parking Management System* are modulated and can be substituted for any other similar system or hardware. The proposed *Modular Parking Management Platform* is independent of the operation system on PC and can be embedded in any other modulated parking system or hardware. The real test and verification proves that the proposed *Modular RFID Parking Management System* can certainly reduce the total cost of RFID parking system infrastructure without re-modifying the existed hardware.

Key-Words: RFID, Parking Management, Embedded, System Integration, Modular.

1 Introduction

RFID today is the popular wireless induction system [5-7, 11-19]. Each RFID tag in RFID system is given a unique ID (UID). When an independent RFID tag approaches the RFID antenna, the induction between tag and antenna happens. The information and content recorded in the tag is transmitted to the RFID antenna and translated into the computational data. Following up the data translation, the tag recognition can be completed and related applications are provided.

Due to the popularity of RFID, the local or small area wireless applications were proposed [16-21]. The RFID tags were proposed to be used in hospital or health care [2-4]. Patients should always wear the designed RFID tag. The patient's current location and condition is monitored every time and everywhere within the hospital. In other words, patients are under cared even an emergency state happens.

In addition, some entrance guard systems are also based on RFID system. The RFID ticket or RFID card [5-7, 12] is used to identify that a user is legal or not. According to the short-distance wireless signal, the RFID tag users can be monitored within the specific area.

However, most of these applications are based on the indoor environments or be a tiny area service [19] and independent of the existed system. The application is established without integrating the existing system or just with the assumptions of existing system integration. Some applications even only focus on embedding RFID into a small device such as handheld host [1]. The handheld device users can be plugged in the SD or CF interface of reader card. Hence, the users can scan and induct the RFID tag everywhere.

In opposition to creating new execution or service environment, there were many existed systems or applications deployed. Since these existed systems or applications run for a long time and present the stability themselves, to include the original systems or applications can reduce the time for stability testing and cost of new infrastructure establishment.

In other words, to enhance the universality of RFID system, an embedded RFID application that suits to any existed

system is important [11].

In this paper, a realistic application, *Modular RFID Parking Management System* (MPMS), is proposed. Via using the proposed system, the main contributions are:

1) the efficiency of management can be improved,
2) the *Modular RFID Parking Management System* is modular and can be embedded in other similar parking system and hardware without additional re-modification,
3) the procedure of passing the Inlet & Outlet can be simplified,
4) the costs of the real construction for *Modular RFID Parking Management System* can be decreased and estimated.

The remainder of this paper is organized as follows. In Section 2, the proposed *Modular RFID Parking Management System* is presented. The real states of using *Modular RFID Parking Management System* are shown in Section 3. At last, the conclusion is given in Section 4.

2 Modular RFID Parking Management System

Due to the demand of existed system integration, the proposed *Modular RFID Parking Management System* includes three sub-systems:

1) *Modular Gate-PC Controller and Embedded Gate Hardware*,
2) *RFID System*,
3) *Modular Parking Management Platform*.

The system framework is shown as Fig. 1. The *RFID System*, original gate hardware, and other business management system colored blue in the framework are independent of the whole MPMS. In this paper, these independent systems are the already existed systems. Each existed systems can independently and individually work without *Modular Parking Management Platform*. For example, the lane gate management was controlled by the manual operation or parking ticket machine without *RFID System* and *Modular Parking Management Platform* added.

It means that these independent sub-systems can be substituted. The gate hardware can be the product of any possible company. There are also many RFID hardware providers. Moreover, to suitably manage and monitor the parking place, the manager may need the attendance information of different users according to each business application. Hence, different type hardware or products need the general interface to communicate with the main management system. To provide the interactive ability of different systems or hardware, *Modular Gate-PC Controller and Embedded Gate Hardware* is proposed to be the intermediary software to hardware interface (gate to PC interface). In addition, RFID API and RFID parser are used to be the middleware between any possible *RFID System* and the *Modular Parking Management Platform*. Furthermore, to communicate with the independent business application, the software API is included in the *Modular Parking Management Platform*. In the following section, each module in the proposed system, *Modular RFID Parking Management System*, is introduced.

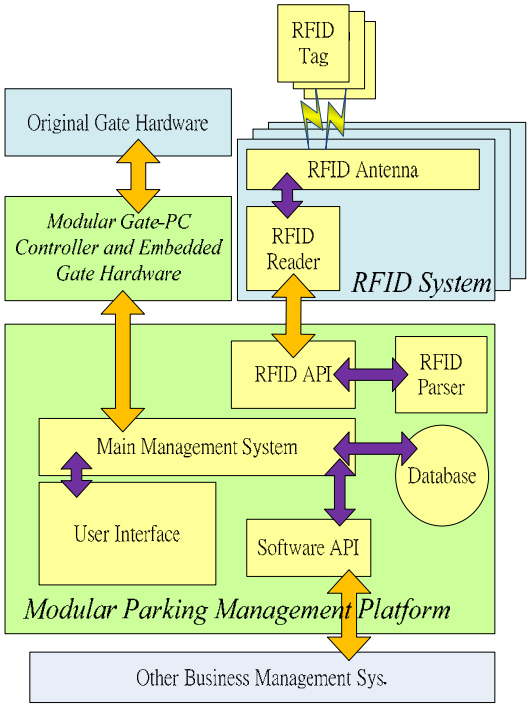

Fig. 1. The framework of *Modular RFID Parking Management System*

2.1.RFID System

The *RFID System* consists of antennas, a

reader, and RFID tags. Each RFID tag records a unique ID and finite information. The tag is triggered when it approaches the antenna [14]. The information recorded in the tag is transmitted through the antenna to the RFID reader. A RFID reader will parse the signal into the digital and computing content.

In the proposed *Modular RFID Parking Management System*, the RFID antennas and reader are deployed at the gate. In addition, the RFID tags are placed in the car. Considering the practicability, the *RFID System* should overcome the accuracy affection of weather and sunshade-paster of car, and the RFID tag type. To increase the usability of the proposed system, the UHF type of RFID tag in this paper is selected.

When an *Modular RFID Parking Management System* (MPMS) user's car approaches the gate, the induction and communication between RFID tag inside the car and antenna of *RFID System* is automatically established. Then the reader of *RFID System* translates the signal information to the digital content. Fig. 2 presents the work flowchart of the *RFID System*.

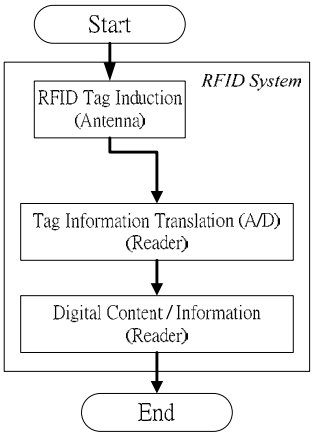

Fig. 2. The work flowchart of the *RFID System*.

2.2.Modular Gate-PC Controller and Embedded Gate Hardware

For the purpose of establishing an embedded system, the *Modular Gate-PC Controller and Embedded Gate Hardware* consists of two partitions:

1) *Embedded Gate Hardware*, and
2) *Gate-PC Controller*.

Due to communication between PC and gate hardware is based on the real signal data transmission, to control the PC hardware IO is needed for *Modular Gate-PC Controller and Embedded Gate Hardware*. The controller corresponds to the operation system of the PC for IO control is important. In this section, the *Embedded Gate Hardware* that based on the real voltage-controlled IO hardware and the *Gate-PC Controller* that controls the PC hardware IO are introduced.

2.2.1 Embedded Gate Hardware

Since there is a existed gate hardware and for the purpose of reducing the cost of establishing the interface, *Embedded Gate Hardware* is proposed to be the middleware for executing the manager's commands and replace or join the original control hardware. To really replace/join the original control hardware, four states of the lane gate should be known first: 1. Inlet gate open, 2. Inlet gate close, 3. Outlet gate open, and 4. Outlet gate close. Hence, to match the control requests of these four states, four individual voltage-controlled IO hardware such as:

1) *InletGate_open*,
2) *OutletGate_open*,
3) *Expansion_1*, and
4) *Expansion_2*

are defined in the paper. The *InletGate_open* is used to transmit a voltage signal to open the inlet gate. The *OutletGate_open* is used to transmit a voltage signal to open the outlet gate. Considering the real gate controller, most gates are closed after counting down an on demand time period. In other words, the control IO for closing the gate can be needless.

Nevertheless, to avoid the requirements of control IO for closing the gate in some gate hardware, the proposed control IO, *Expansion_1*, and *Expansion_2*, can be used when required. In addition, the, *Expansion_1*, and *Expansion_2*, can be the control IO to manage or control another hardware such as the admission light, warning sign, or a parking space counter used in this paper. These control IO are extra-added the original control IO of gate hardware together. It means that the modification of the original gate hardware can be reduced.

2.2.2 Gate-PC Controller

Since the *Embedded Gate Hardware* is based on four voltage-controlled IO hardware, the digital computing commands from the PC to control the gate need to be translated into the voltage signals. In other words, a middleware between *Embedded Gate Hardware* and PC is needed. In this paper, *Gate-PC Controller* which included hardware and software is proposed to communicate with PC and command the *Embedded Gate Hardware*.

To construct the hardware of embedded *Gate-PC Controller*, we use the ADAM digital I/O module [8] as the middleware to construct the computing_commands / voltage_signal module.

ADAM-4520 is the RS-232/RS-485 converter module that communicates with host PC via RS-232 link. The digital computing command from the host PC is converted into the RS-485 type data stream. Fig. 3 shows the converter module.

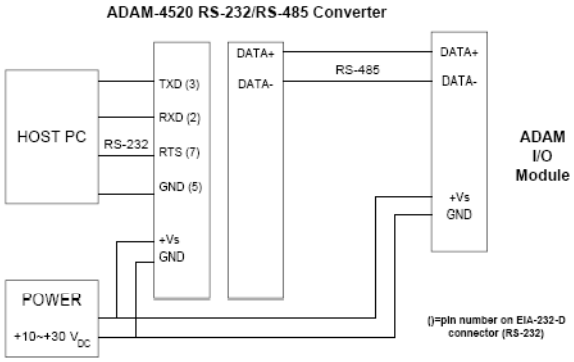

Fig. 3. The Module of ADAM-4520.

Then, the converted data is inputted to the module ADAM-4050. The output DATA+ of ADAM-4520 is connected to the DATA+ of ADAM-4050 and also is the DATA-.

In addition to hardware, a software program is executed. This program is designed corresponding to ADAM. The program sends the commands from host PC to the hardware of *Gate-PC Controller* via RS-232. Then, to command the gate hardware, the voltage_signals are sent from the data output, DO0, DO1, DO4, and DO5 of ADAM-4050 to the gate hardware through *Embedded Gate Hardware*.

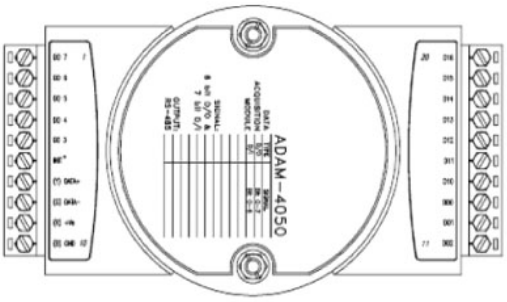

Fig. 4. I/O Module of ADAM 4050.

2.3.Modular Parking Management Platform

The *Modular Parking Management Platform* mainly includes

1) RFID parser, RFID API,
2) software API,
3) and main management system.

Since the *RFID System* can be e any possible RFID product, the proposed platform provides the RFID parser and RFID API to communicate with different type of RFID products. After translating the RFID tag information to digital content, the digital content is delivered to the *Modular Parking Management Platform* via network. However, different *RFID System* may translate the signal to different type of digital content. Or, different *RFID Systems* deliver the content included in different types of data packets. Hence, when the digital content is sent to the *Modular Parking Management Platform*, the RFID API checks the type of content via querying the RFID parser. The RFID parser provides and selects a suitable translation function (or method) to analyze the content and gain the information about the current RFID tag. Then the information can be managed by main management system.

Not only gaining the requested RFID information but also managing the information is important. In this paper, when the main management system receives the RFID information, the system checks that this RFID is legal or not. Only the valid RFID can go on the procedures.

If the RFID is valid, the main management system automatically sends the command to open the inlet or outlet gate through *Modular Gate-PC Controller and Embedded Gate Hardware*. The correct gate now is opened. At the same time, the related

state information of this RFID tag recorded in the database is updated. Furthermore, the current states of the lane gate and the parking space are shown in the proposed user interface.

As shown in the framework above, the *Modular Parking Management Platform* may need to interact with other software such as staff attendance management system. To be capable of interacting with other systems or applications, the software API is proposed to communicate with others based on network protocol such as socket protocol. In other words, any application which can send and receive the data via socket can be included and interact with the *Modular Parking Management Platform* through software API.

In addition, since there existed a middleware, *Modular Gate-PC Controller and Embedded Gate Hardware*, for the gate control, the proposed platform can suit the different types of gate hardware without additional modification. The flowchart of *Modular Parking Management Platform* is shown as Fig. 5.

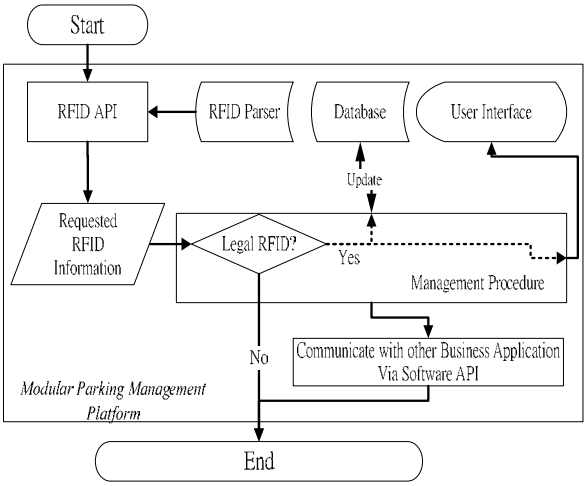

Fig. 5. The flowchart of *Modular Parking Management Platform*

2.4.Modular RFID Parking Management System

When an *Modular RFID Parking Management System* (MPMS) user's car approaches the gate, the *RFID System* procedure is automatically executed. After the content translation, the reader of *RFID System* transmits information obtained from the tag to the *Modular Parking Management Platform* via Internet.

When the *Modular Parking Management Platform* receives the information from RFID reader, the information of the tag is judged. According to the decision made by the *Modular Parking Management Platform*, only the car with the legal or valid tag can enter the gate.

Then, the management procedure will update the current state of the car corresponding to the RFID tag recorded in the database. In addition, the commands are transmitted through the *Modular Gate-PC Controller and Embedded Gate Hardware* to open the gate at the same time. Furthermore, the current states of the parking lane, parking space, and the user's car are presented for the management via user interface. If the information needs to be passed to other systems or applications, the software API sends the required information via socket protocol at the same time. The whole flowchart of the proposed system is shown as follows.

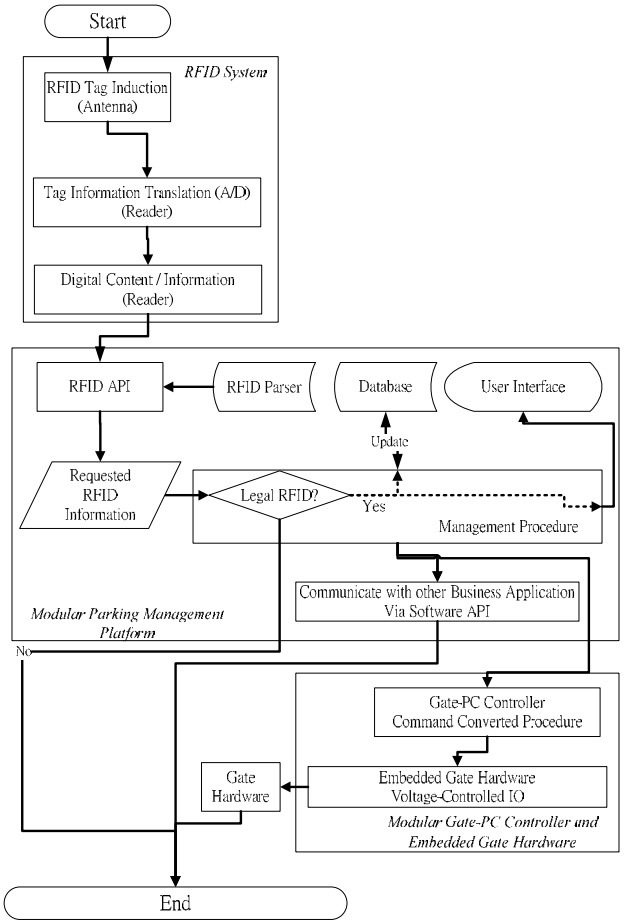

Fig. 6. The whole flowchart of *Modular RFID Parking Management System.*

3 Implementation

To real test and verify the proposed *Modular RFID Parking Management System*, we develop the *Modular Parking Management Platform* in Java language. In other words, the developed *Modular Parking Management Platform* is independent of the operation system of the PC. The software API of *Modular Parking Management Platform* based on the Java server socket protocol can communicate with other business applications. In addition, communication between the RFID API and RFID reader is also based on the Java server socket protocol.

ThingmMagic [9] RFID reader and antenna are selected for the real implementation. The RFID tag product of International Semiconductor Technology Ltd. (IST) [10] is used for client's car.

Due to the PC hardware IO control is needed for *Modular Gate-PC Controller and Embedded Gate Hardware* to transmit command data and open gate, the software of *Modular Gate-PC Controller* corresponds to the operation system of the PC is important. In this paper, the operation system of the host PC is Microsoft Windows XP. Hence, the software of *Modular Gate-PC Controller* is created based on VB/C language. The software of *Modular Gate-PC Controller* is an always-executing program to wait (or listen) the commands from *Modular Parking Management Platform* every time.

In addition, the communication between the database (other business management system) and *Modular Parking Management Platform* is based on Ethernet and Java server socket. The link between ADAM and *Modular RFID Parking Management System* server PC is RS-232.

The real implementation is presented in Fig. 7.

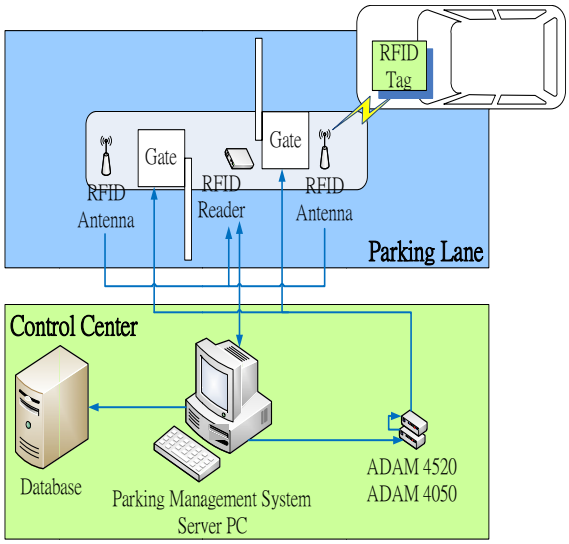

Fig. 7. The real implementation of *Modular RFID Parking Management System*

3.1.RIFD System

The *RFID System* consists of the RFID tag, antenna, and RFID reader. The connection between antenna and reader is established via coaxial cable. In this paper, the real implementation of *RFID System* is shown as Fig. 8. The RFID antenna is set about 2 m before the fence machine of the lane gate.

Fig. 8. The real implementation of *RFID System*

To guarantee the stability and accuracy of RFID tag detection and identification within the finite time, the power of antenna is set as 30 dBm and the power state of antenna and reader are always on. The mode of the ThingmMagic RFID reader is set as Auto Mode which indicates that a 500 milliseconds time period consists of 250 milliseconds querying for tag and 250 milliseconds with RF off. The protocol for RFID antenna to communicate with RFID

tag is EPC Global Generation 2. In addition, the ThingmMagic RFID reader provides the Ethernet port and can connect to the IP-based network directly. In this paper, a DHCP service is adopted for the network.

Considering the performance of RFID tag, two types of the IST's tag with size 4.40"X4.125" that for polyester and that adhesive to glass are used. Fig. 9 shows the tag used in *Modular RFID Parking Management System*.

Fig. 9. The RFID tag of IST used in *Modular RFID Parking Management System*.

Each RFID tag is assembled by anti-UV material. For the purpose of testing the affection of sunshade-paster and weather, the implemented *Modular RFID Parking Management System* is also tested in the sunny days, rainy days, whether the car with the sunshade-paster or not. The related parameters of *RFID System* are shown in Table 1.

Table 1. The related parameters of *RFID System*.

Power Output	30 dbm +/- 1.00 db	
RFID tag and protocol	EPC Global Generation 2	
RFID Tag	size 4.40"X4.125"	
	Polyester Label	Adhesive to glass
Frequency	ETSI 865.6-867.6 MHz MIC 910-914 MHz FCC 902-928 MHz	
I/O used	Ethernet for reader of *RFID System*	
IP	DHCP given (different from *Modular Parking Management Platform* PC)	

3.2.Modular Parking Management Platform

The *Modular Parking Management Platform* based on Java language is independent of operation system. The RFID API uses socket to communicate with the RFID reader. To managing the real time events from the RFID reader, the main management system runs thread environment. In this paper, the proposed platform runs based on the PC and related parameters are shown in Table 2. Since the reader of *RFID System* is connected to the IP-based network, the RFID API of *Modular Parking Management Platform* based on Java server socket protocol can communicate with reader of *RFID System* according to the on demand given IP address of this reader.

Table 2. The related parameters of PC for *Modular RFID Parking Management System*.

CPU	Core 2 Dual 1.66GHz
Memory	1 G DDRII RAM
HDD.	At least 200MB
O.S.	Microsoft Windows XP
I/O	RS-232 for ADAM Ethernet for reader of *RFID System*
IP	DHCP given (different from that of the reader of *RFID System*)

The user interface of *Modular Parking Management Platform* uses Java AWT API. The real-time state of inlet and outlet parking lanes are shown in the user interface. When a car with the RFID tag approaches the gate, the information of this RFID tag gained from *RFID System* is presented. In addition, the information of the last car (or person) which enters the inlet or outlet gate is individually shown in the user interface. The current total number and states of occupied parking space are presented in red color for occupied and black color for available. Furthermore, the records correspond to the RFID tag in the database are also updated and shown.

The system user interface is shown as follows.

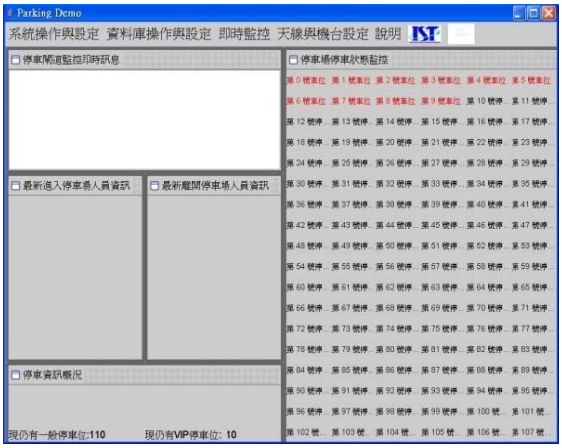

Fig. 10. The user interface of *Modular RFID Parking Management System*.

To enable the communication with other business management system, the software API of *Modular Parking Management Platform* uses Java server socket protocol and file IO in this paper. The managers can monitor the current state of the *Modular Parking Management Platform* or the real-time states of parking space via other applications such as web browser. In this paper, the *Modular Parking Management Platform* provides the html type of presentation for remote managers. Fig. 11 presents the remote user interface shown by web browser.

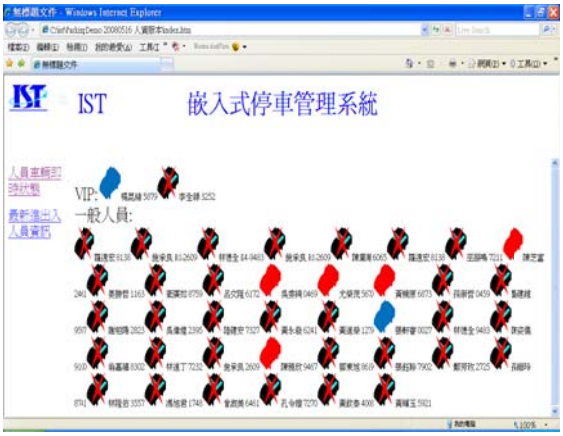

Fig. 11 The remote user interface shown by web browser

3.3.Modular Gate-PC Controller and Embedded Gate Hardware

To control the original and existed gate hardware, the four individual voltage-controlled IO hardware are linked. If the *InletGate_open* which connected to the DO0 of the ADAM-4050 of *Gate-PC Controller* is set a signal with the voltage 12V, the inlet fence of the gate is opened. After 6 seconds counting down the inlet fence of the gate closes automatically. The *OutletGate_open* which which connected to the DO4 of the ADAM-4050 of *Gate-PC Controller* controls the outlet fence of the gate and opens it when is set a signal with voltage 12V. In addition, the *Expansion_1* and *Expansion_2* of *Embedded Gate Hardware* are connected to the DO1 and DO5 of the ADAM-4050 of *Gate-PC Controller* individually. If the *Expansion_1* is set a signal with voltage 12V once, the counter which counts and presents the total number of current available parking space subtract 1. In opposition to *Expansion_1*, the *Expansion_2* is set a signal with voltage 12V once to add 1 from the current total number of available parking space. When a valid car approaches the inlet gate, the *Modular Parking Management Platform* sends commands to *Gate-PC Controller* which will set the DO0 and DO1 a signal with voltage 12V.

3.4.Real Presentation and Result

The real test and verification is implemented in IST. The RFID tags are put in different cars for performance evaluation. Fig. 11 shows one shoot of the verification. The mobility of the car is limited and lower than 30 km/hr. The RFID tag is placed left inside the car due to the antenna location of *RFID System*.

Fig. 11. The environment of test and verification.

According to the verification, the results are presented in Table 3. The whole dynamic test and verification is presented in http://www.wretch.cc/video/jianms&func=si

ngle&vid=4167314&o=time_d&p=2.

In this paper, the induction distance is defined as: an RFID tag can be inducted continuously and the signal transmission between tag and antenna is never interrupted.

The verification shows that the induction distance from antenna to the RFID tag depends on the type of tag. The material and weather take affection. RFID tag assembled by polyester has the better ability of weather resisting. When test in the rainy day, there is a layer of water and mist. It apparently reduces the transmit distance about 16~33% especially more than 50% when there is a layer of water on the glass with the RFID tags that adhered on glass.

In addition, the verification also shows that the distance from antenna to the RFID tag is normally about 4 m of polyester type tag and about 2 m of that adhered on glass. In other words, there are at least 6 m from the fence of the gate to the car since the antenna is located 2 m before the fence of the gate. It means that there will be more than 0.7 seconds (if the mobility of the car is limited and lower than 30 km/hr) for the proposed *Modular RFID Parking Management System* to open the fence of lane gate. Therefore, in most cases, the fence of the lane gate can open in time and the car can enter the gate into parking lot smoothly. In this paper, the procedure time T is defined as that

$$T = t_f - t_a \quad (1)$$

where t_f is the time of fence opening and t_a is the RFID tag induction time of the *RFID System*. In this paper, the procedure time is less than 1 second and satisfies most situations and cases of *Modular RFID Parking Management System*.

To evaluate the identification accuracy, the evaluation function is defined as:

$$\text{identification accuracy} = \frac{\sum_{i=1}^{n} \text{Induc}(\text{tag}_i)}{\sum_{i=1}^{n} \text{Test}(\text{tag}_i)} \quad (2)$$

where n is the total number of tested RFID tag, tag_i indicate the i^{th} tested RFID tag, $\text{Induc}(\text{tag}_i)$ means the total number or times of the i^{th} tested RFID tag that inducted, and $\sum_{i=1}^{n} \text{Test}(\text{tag}_i)$ indicates t the total test times of the i^{th} tested RFID tag.

The verification results show that the RFID tag assembled by polyester can achieve 99.75% identification accuracy. In opposition to the polyester type RFID tag, the tag that adhered on glass is affected by the material and thickness of sunshade. Under the situation of car window closed, the identification accuracy is only 45% when dark or thick sunshade used. In opposite, the accuracy reaches 85% if only limpid or normal sunshade used. However, if the window of the car is opened, the identification accuracy can also reach 99.75% without changing induction distance. It means that although the identification accuracy is affected by medium material such as glass, the sunshade used, and weather.

In other words, the proposed *Modular RFID Parking Management System* with suitable RFID tag selected can still achieve the high identification accuracy within different weather.

Table 3. The verification results of *Modular RFID Parking Management System*.

Material	Polyester	Adhesive to glass
Accuracy (Lab)	100%	
Accuracy (Real)	99.75%	45% * Dark or Thick Sunshade
		85% * Limpid or Normal Sunshade
Induction Distance (Sunny)	3~6 m	2~4 m
Induction Distance (Rainny)	2~5 m	Less than 2 m
Procedure Time+	<1 Sec	

* the accuracy value can be 99.5% when the window of car is open.

4 Conclusion

In this paper, an embedded application, *Modular RFID Parking Management System*, is proposed to integrate the existed gate

control system and other business management systems such as database. The proposed *Modular RFID Parking Management System* provides APIs which correspond to the existed systems and enables these systems as the modules of the proposed *Modular RFID Parking Management System*.

Modular Gate-PC Controller and Embedded Gate Hardware can be the middleware between the existed gate hardware and host PC with less additional cost of integration and less modification.

The *RFID System* is independent of the *Modular Parking Management Platform* and can be a customization selection.

Modular Parking Management Platform includes the API module and related parser that can easily embed other systems in. The main management system can communicate with *RFID System* by proposed RFID API and RFID parser, other business management system via software API, and control the fence of the lane gate by the middleware *Modular Gate-PC Controller and Embedded Gate Hardware*. The current situation of lane, parking space, and related user information can be correctly presented by user interface.

The verification shows that the *Modular RFID Parking Management System* is realistic and can control the parking automatically. The response time delay is within 1 second. By using the RFID assembled by polyester, the identification accuracy can achieve 99.75% with distance more than 2 m that independent of weather. The total cost of *Modular RFID Parking Management System* infrastructure can be reduced.

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