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Development and evaluation of an RFID-based e-restaurant system for customer-centric service

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ABSTRACT

Traditional restaurant service is passive: waiters must interact with customers directly before processing their orders. However, a high quality customer-centered service system would actively identity customers, their favorite meals and their expenditure records. To achieve this goal, this study integrates radio frequency identification (RFID), wireless local area network (WLAN) and database technologies to develop an e-restaurant system for customer-centric service, which enables waiters to immediately identify customers via RFID-based membership cards and then actively provide customized services. The user interface of the proposed system is built with Visual C# 2005 and eMbedded Visual C++, and the database is built on Microsoft SQL Server 2005 for Server management and statistic reporting. The WLAN and RFID technologies are used to transmit real-time information of each dining table. To verify the effectiveness of the proposed system, a series of experiments was conducted in two restaurants. A questionnaire survey administrated to waiters and customers confirmed the effectiveness of the proposed e-restaurant system in providing customer-centric service. Furthermore, extensive interviews with restaurant owners revealed very positive feedback.

1. Introduction

Restaurant service processes such as making reservations, ordering, and delivering the meal generally require waiters to record customer orders and then transmit them to the kitchen for preparation. When the customer pays the bill, the amount due is calculated by the cashier. Although this procedure is very simple, it may significantly increase the workload of waiters and even cause errors in meal ordering or in prioritizing customers when the number of customers suddenly increases during busy hours, which can serious degrade overall service quality. Therefore, using advanced technologies to improve service quality has received much attention in recent years. For instance, the counter system of many fast food restaurants in Taiwan is equipped with a touch-screen, keypad or mouse control interface to enable cashiers to address customer needs. Such systems usually have common point of sale (POS) functions which allow waiters to use an optical scanner to directly read 2D barcodes for order details and billing. However, the POS system requires the waiter to determine customer needs and then enter the information. Therefore, service can only be provided passively.

However, a high quality service system should be customer-centered, i.e., it should immediately recognize the identities, favorite meals and expenditure records of customers so as to provide customer-centric services. To achieve this goal, this study integrated radio frequency identification (RFID), wireless local area network (WLAN) and database technologies to implement a customer-centric service system that enables waiters to immediately identify customers via their own RFID-based membership card and then actively provide customized services. Customers can also use the RFID-based membership card to pay bills instead of using cash. Moreover, to enhance dining table service, the proposed system enables access by personal digital assistant (PDA). The PDA-based service unit enables instant transmission of customer orders via WLAN to the kitchen for meal preparation. Also, the expenditure information can be sent to the cashier for pre-processing of bill. The restaurant managers can access the database to evaluate the business status anytime and make appropriate redeployments for food materials. Notably, all ordering and expenditure information is digitized for database storage, which allows restaurant owners to consider discounts or promotions to customers based on expenditure statistics. Customers can thus appreciate high quality service, and the image and business revenue of the restaurants can also be significantly enhanced.

To verify the effectiveness of the proposed system, a series of experiments was conducted in two restaurants, and a questionnaire survey was administrated to waiters and customers. Several in-depth interviews were also conducted with restaurant owners. The rest of this paper is organized as follows. In Section 2, a brief

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literature review on previous RFID applications is presented and the technology acceptance model (TAM) is described. Problem statements for the traditional restaurant and possible solutions are described at Section 3. Section 4 describes the implementation details in the e-restaurant system. Experimental results are demonstrated in Section 5. Section 6 discusses the RFID benefits and challenges: lessons from the case study. Finally, conclusions and future works are given in Section 7.

2. Literature review

RFID has been identified as one of the ten greatest contributory technologies of the 21st century. RFID technology features remote distance reading ability, larger memory capacities and reading range, and faster processing than bar codes, and identification of objects or human beings. An RFID tag consists of a microchip and an antenna. The RFID reader/writer requests the identifying information contained in the microchip by sending an RF signal to the tag, which then wirelessly transmits the information to a reader/writer. The reader then digitizes the information and sends it to the application software with the help of middleware. The encoder, often the RFID reader/writer itself, encodes the data for storage in the tag once or many times, depending upon whether the RFID tag is a read-only tag or a read-write tag.

Due to its many advantages, RFID has been applied in many areas, such as supply chain management, telemedicine, manufacturing, inventory control, construction industry, warehouse management, and digital learning. In 2003, Wal-Mart, a leading US retailer, implemented an RFID system for tracking supplies (Tajima, 2007). Wal-Mart and other companies anticipate significant benefits in their own supply chains and believe that, in the long term, RFID can also benefit their suppliers. The potential benefits of utilizing RFID technology for suppliers include reduction of operations costs, optimization of inventory management and increased information accuracy (Chuang & Shaw, 2007), and improvement of customer relationship (Lin, Lo, & Chiang, 2006). Xiao, Shen, Sun, and Cai (2006) proposed two RFID applications in telemedicine to investigate supply and demand of doctors, nurses and patients in hospitals and healthcare and to develop mobile telemedicine services. They also performed a comprehensive survey of security and privacy issues in RFID systems and suggested their solutions. Bal (2007) deployed an RFID system on a college campus to guide visually impaired pedestrians. In this implementation, all campus walkways were embedded with electronic tags connected to a Path Finder application Server. Current user location could be identified by RFID tags, and the RFID tag reader actively provided voice information of the location to guide the user. Liu (2007) applied RFID technology to resolve two manufacturing logistics problems arising in IC packaging houses: manual operational errors in the wafer receiving process and incapability electronic transaction process for inventory control. Also, this study developed an electronic material flow control system by employing RFID technology, a RosettaNet network and ERP system. Then the electronic material flow control system was implemented in a local IC packaging company. The experimental results revealed substantial benefits, including reduced operator workload, increased productivity and increased accuracy and speed of information processing. Domdouzis, Kumar, and Anumba (2007) briefly introduced applications of RFID technology for the uninitiated reader without going into the technical and mathematical details. In their study, RFID is used successfully for the tracking of pipe spools, structural steel members and as an on-site support system. Chow, Choy, Lee, and Lau (2006) proposed an RFID based resource management system (RFID-RMS) that integrated the RFID, case-based reasoning and the programming model technologies to help users to select the most suitable resource usage packages for dealing with warehouse operation orders. The practical application of RFID-RMS in a company revealed that the utilization of warehouse resources is expected to be maximized while working efficiency will be significantly improved. Furthermore, RFID technology was recently adopted in Poon et al. (2009) to facilitate the collection and sharing of data in a warehouse. In this study, comprehensive tests were performed to evaluate the reading performance of both the active and passive RFID modules. The efficient radio frequency cover ranges of the readers are then examined based on the testing results for formulating a radio frequency identification case-based logistics resource management system (R-LRMS). A successful case example achieved in a company demonstrated the feasibility of R-LRMS in real working practice. Tan, Liu, and Chang (2007) developed a ubiquitous learning environment with educational resources (EULER) based on RFID, the Internet, ubiquitous computing, embedded systems and database technologies to enhance teaching in outdoor environments and to cultivate student ability to use information technologies for assisting learning. The experimental results showed that RFID sensor technology was effective in providing context-aware and ubiquitous learning experiences.

In recent years, RFID technology has been adopted in the food supply chain to enhance the traceability of food. Karkkainen (2003) indicated that adopting RFID technology can improve replenishment productivity as well as reduce stock loss in the supply chain of short-shelf-life products. Jones, Clarke-Hill, and Hillier (2005) reported that RFID technology can be used throughout the supply chain for the UK retail foods industry, including tighter management and control of the supply chain, reduced shrinkage, reduced labour costs, improved customer service and improved compliance with traceability protocols and food safety regulations. Chen, Chen, Yeh, and Kuo (2008) proposed an integrated traceability system for the entire food supply chain by RFID technology. In their study, the food production can be traced so that consumers can get the complete food production information to choose and buy the safety food. Kumar and Budin (2006) also concluded that RFID plays a crucial role in the prevention of food product recalls.

Recently, Chao, Yang, and Jen (2007) analyzed the contributions of the RFID industry and forecasted technological trends via a historical review and bibliometric analysis. Their review indicated that the major emerging issues of RFID are supply chain management, health industry applications and privacy issues. This study also demonstrated that the contribution of various enterprises to the adoption of RFID can be divided into four categories according to managerial perspective and enterprise opportunities: (1) identifying objects and persons, (2) tracking process flow, (3) authentication, authorization and security and (4) financial recordkeeping. Most importantly, Chao et al. (2007) predicted the ubiquitous diffusion and assimilation of RFID into daily life in the near future.

Many organizations devote considerable resources and knowledge to reconfigure and create innovative new structures in order to conquer the issues in mobile commerce such as user security and privacy, low-quality wireless connectivity and limited screen size of hand-held device (Li, 2005), improve the cost-effective of operations (Edwards, Delbridge, & Munday, 2005) and gain economic benefits (Szántó, 2005). While RFID has successfully been employed in many areas, further exploration of its innovative applications is needed to enhance competitive advantage of enterprises and quality of life. For example, innovative applications of RFID are still rare in the restaurant industry. Recently, Ngai, Suk, and Lo (2008) developed an RFID-based sushi management system in a conveyor-belt sushi restaurant to enhance competitive advantage. Their case study showed that RFID technology can help improve food safety, inventory control, service quality, operational efficiency and data visibility in sushi restaurants. As competition between restaurants intensifies, restaurants must integrate innovative technologies with business management processes to enhance customer service and improve competitiveness (Kumar, Karunamoorthy, Roth, & Mirnalinee, 2005). This situation motivated the development of this RFID-based e-restaurant system with customer-centric service to enhance customer satisfaction and perceived value (Lee, Fiedler, & Smith, 2008).

The technology acceptance model (TAM) and its modified version (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989) have been widely used to evaluate user acceptance of various information technologies. The TAM analyzes perceived usefulness and perceived ease of use to determine user intentions to use information technology. Perceived usefulness is defined as the extent to which individuals believe their job performance is enhanced by using a particular technology. Perceived ease of use is defined as the extent to which an individual believes that using a particular system is free of effort. The TAM also postulates that perceived ease of use predicts perceived usefulness (Chin & Todd, 1995; Doll, Hendrickson, & Deng, 1998). Hossain and Prybutok (2008) used TAM to predict consumer acceptance of RFID technology and revealed the following findings:

(1) Increased perceived convenience of RFID technology leads to greater acceptance of this technology.
(2) Societal beliefs, value systems, norms and/or behaviors influence the extent of consumer acceptance of RFID technology.
(3) Higher perceived importance and less willingness to sacrifice personal information security reduce intention to use RFID technology.

The TAM will be employed in our study to evaluate the effectiveness of the proposed e-restaurant system.

3. Problem statements for traditional restaurants and solutions

Fig. 1 shows a comparison of service procedure between traditional restaurants and e-restaurants. The service procedure of a traditional restaurant includes customer arrival, escorting the customer to a proper seat, taking the order, and submitting the order to the kitchen for meal preparation. When a customer pays the bill, the amount due is also calculated by the cashier. However, the attendant in an e-restaurant can use a PDA equipped with an RFID reader to access customer information and service history from a back-end database and then actively provide customized services such as suggesting favorite meals and offering special meal information. Fig. 2 presents problems encountered in traditional restaurants and corresponding strategies for solving these problems by using electronic devices. Customer preferences, amount due, consumption ability, and food trends revealed by customer consumption records are analyzed to design different food dishes that satisfy customer needs. Further, construction of a real-time updating web page that shows

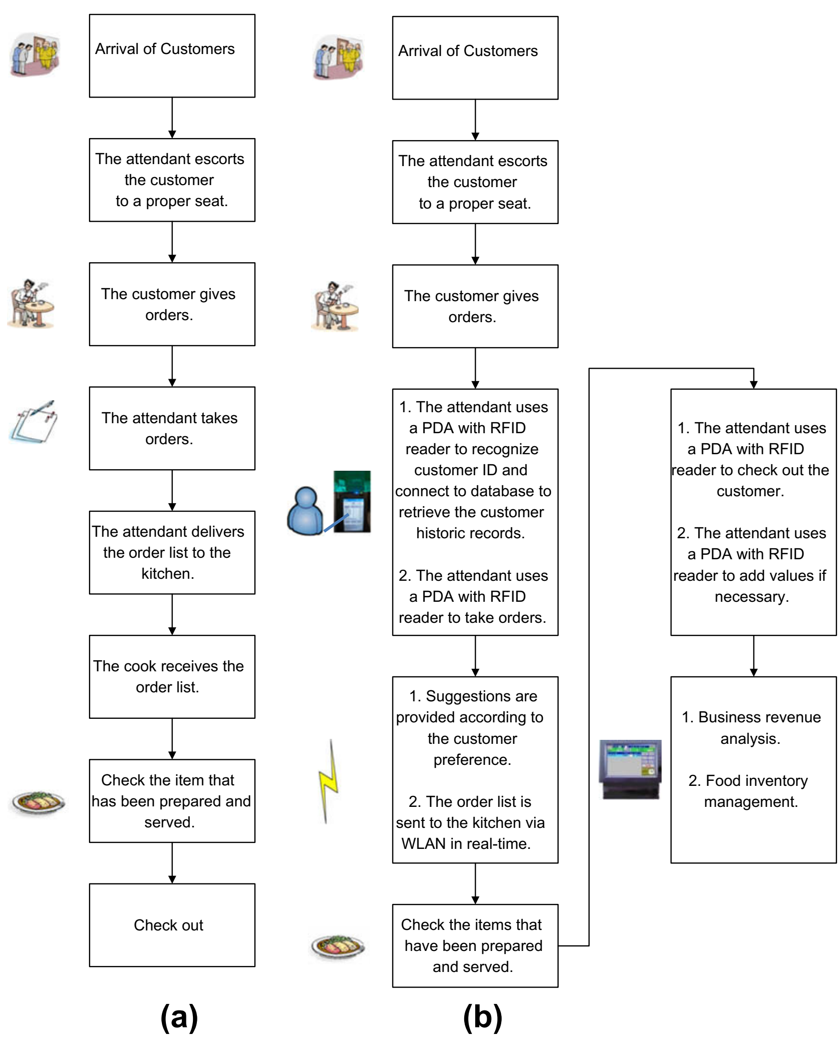

Fig. 1. A comparison of service procedure between traditional restaurants and e-restaurants. (a) The service procedure of traditional restaurants; and (b) The service procedure of e-restaurants using electronic devices to improve working efficiency and reduce human labour of waiters.

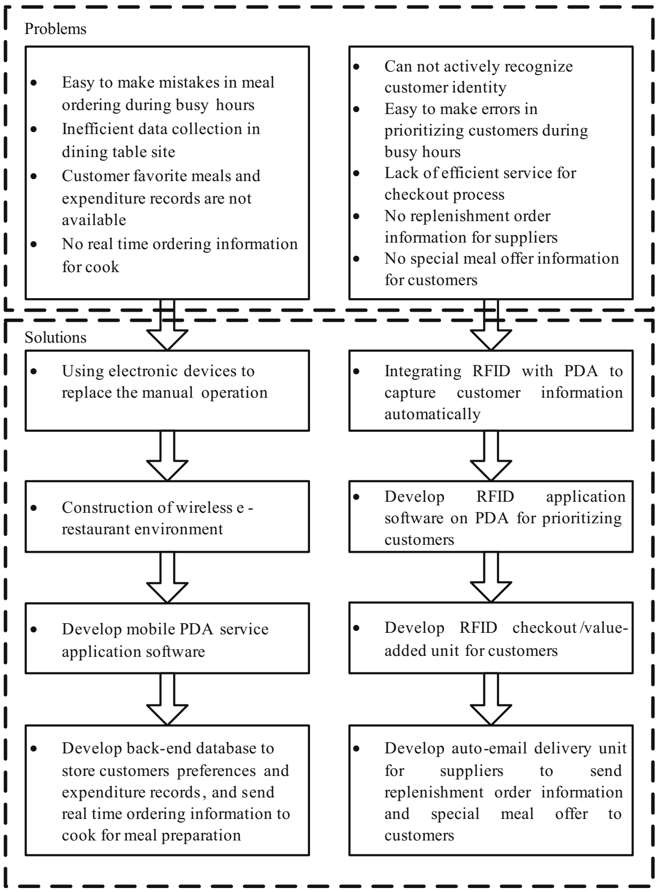

Fig. 2. Problems statement for traditional restaurants and solutions.

the status of each table and the number of current customers is proposed. These problems and solutions are as follows.

Problem 1 (*Taking orders*). In traditional restaurants, waiters write down customer orders and needs. This order-taking task may be a heavy workload for wait staff, which may make mistakes during busy hours. Any mistake can cause chaos and can affect overall service quality and customer satisfaction.

Problem 2 (*Recognizing customer identity and preference*). To improve the relationship between servers and customers, customer data such as consumption history, preferences, and accumulated bonuses should be identified by using the membership ID of the customer to access the database. However, these data are not automatically recognized and provided in a traditional restaurant.

Problem 3 (*Order transfer*). Customer orders are manually transferred to the kitchen for preparation. Since orders may not be delivered to the kitchen immediately due to errors by the server, mistakes in the priority of foods to be served may occur.

Problem 4 (*Checking out*). When customers ask to settle their bills, the cashiers calculate the total bills using the hand-written order lists. If the cashier incorrectly indicates an item or its price, the receivable may be miscalculated. In such a case, satisfactory service is impossible.

Problem 5 (*Managing food materials and customer information*). The amount of each food material is manually estimated in current restaurant inventory systems. The management staff is unable to get hold of the latest inventory of food materials. Moreover, customer information is not considered in traditional restaurants.

Solution 1. Using PDAs to take customer orders can enhance efficiency.

Solution 2. RFID technology can be used to identify customers and retrieve their personal data in real-time. Such personal data, including personal preferences and historic consumption records, can help the restaurant provide customized and high quality services.

Solution 3. Attendants can immediately transmit new orders to the kitchen and cashier via wireless networks. Using wireless technology can reduce the time required to manually submit and record orders. Furthermore, foods can be served according to their respective time of order to avoid mistakes such as serving the last customer first.

Solution 4. Integrating RFID and PDA technologies for use in checking out and value-added provides accurate and efficient services.

Solution 5. A food management module can be developed. Through e-mail delivery, food suppliers can be automatically notified to supply items in shortage. This can enhance the management efficiency. Additionally, e-restaurants can conduct questionnaires to customers after meal on a PDA to immediately realize customers dining needs.

4. System implementation

4.1. Framework of the proposed RFID-based e-restaurant system

Fig. 3 shows an overview of the architectural framework of the RFID-based e-restaurant system for customer-centric service. The chefs could prepare the meal from the message shown on the order display system built in kitchen. The restaurant manager could use the system to view statistics of the current inventory, sales records, staff information, and so on. The waiter could use the PDA to make order for the customer at dining table. The stock-keeper could also use the system to systematically record order information from the suppliers and monitor the available stocks in the shop floor and the refrigerator. In addition, the system will send information and alert to the suppliers as inventory is lower than the stock level. After finishing the meal, the cashier can use an RFID-based PDA to identity the membership card ID, in order to make out the bills. Furthermore, the cashier could use the RFID-based PDA to perform the valued-added for customers.

4.1.1. Hardware structure

Fig. 4 illustrates the hardware structure of the proposed e-restaurant system, which consists of a counter Server with RFID reader, an order display system in kitchen, several PDAs each equipped with an RFID reader and software for dining table service application. This system provides two service models as follows.

1. When a customer carrying an RFID-based membership card enters the restaurant, the RFID reader at counter actively identifies the customer and obtains the customer data and expenditure records. The waiter at the counter makes orders for the customer and the order is shown on the PC screen for confirmation. Simultaneously, the order is transmitted to the order display system via WLAN.

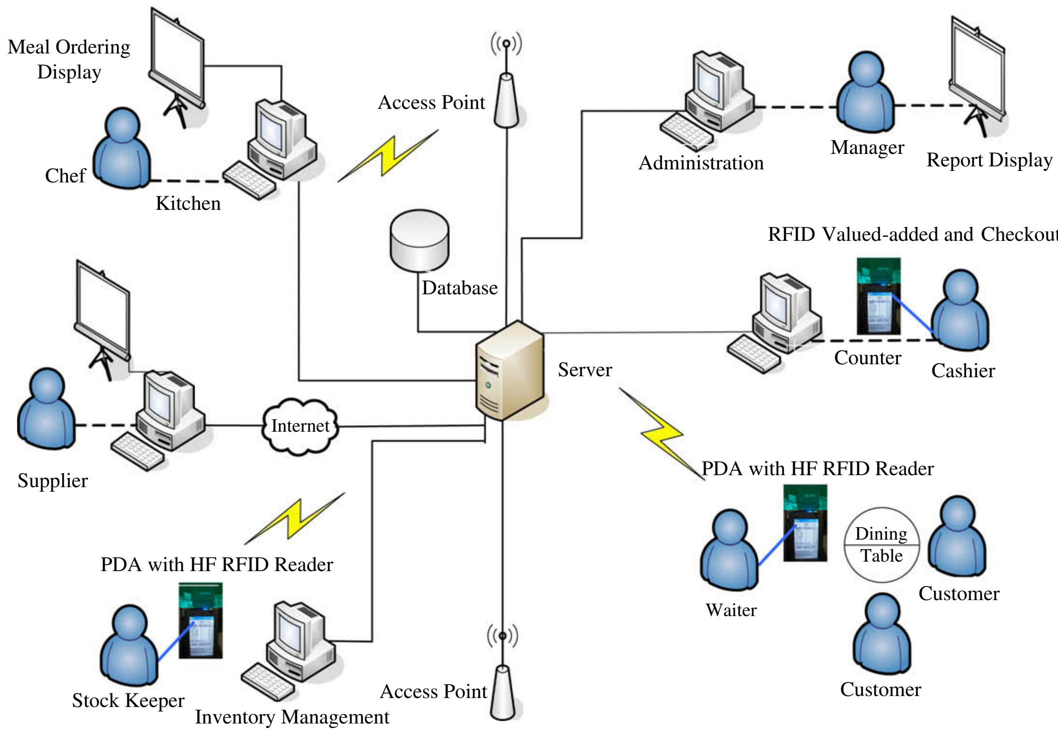

Fig. 3. Framework of an RFID-based e-restaurant system for customer-centric service.

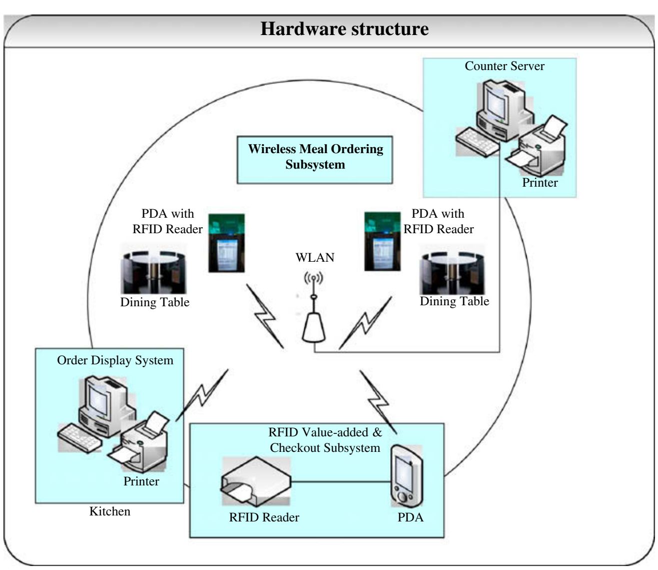

Fig. 4. Hardware structure of the e-restaurant system.

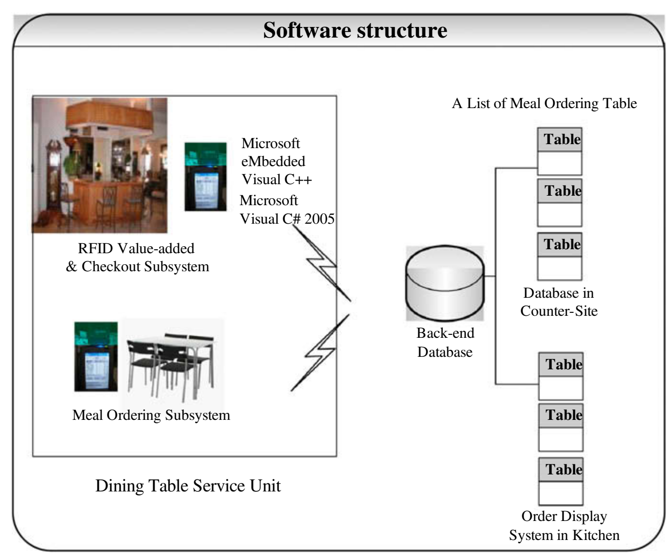

Fig. 5. Software structure of the e-restaurant system.

2. When a customer carrying an RFID-based membership card enters the restaurant and sits at a dining table, the waiter can use a hand-held PDA equipped with RFID reader to take the customer order. The order is shown on the PDA for confirmation by the customer and is then transmitted to the counter Server and the order display system in kitchen via WLAN.

4.1.2. Software structure

Fig. 5 presents the software structure of the proposed e-restaurant system. The structure is comprised of two units. One is the dining table service unit that consists of RFID-based wireless meal ordering subsystem and RFID value-added/checkout subsystem. The other is the back-end database built on counter Server, which can also be accessed by the order display system in kitchen. The RFID-based wireless meal ordering subsystem was developed with Microsoft Visual C# 2005. The RFID value-added/checkout subsystem was developed with Microsoft eMbedded Visual C++. The back-end database was developed with Microsoft SQL Server 2005. We illustrate the implementation of each subsystem in the following.

4.1.3. Implementation of RFID-based wireless meal ordering subsystem

Fig. 6 shows the user interface of the proposed RFID-based wireless meal ordering subsystem. This system actively serves customers and allows the RFID-based membership card to be used as an electronic wallet. When a customer enters the restaurant, the

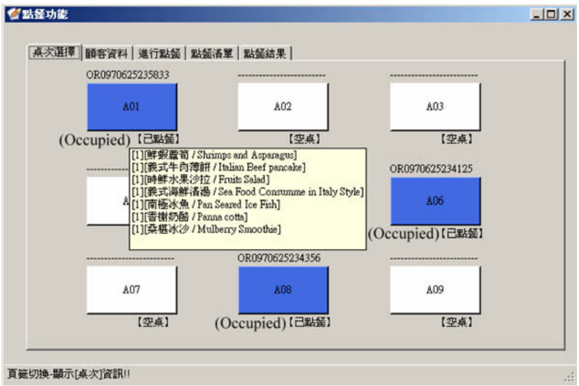

Fig. 6. User interface of the proposed RFID-based wireless meal ordering subsystem.

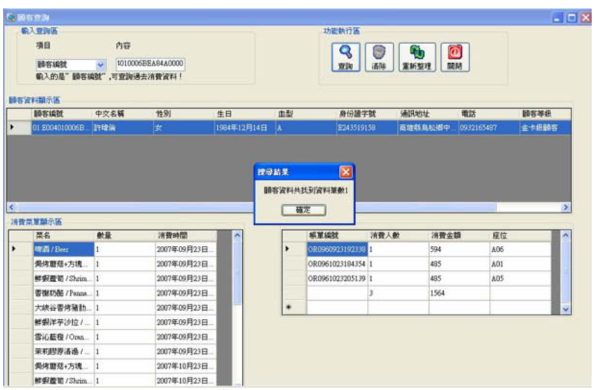

Fig. 7. Customer expenditure records.

counter clerk can check the Server to determine whether any tables are available. If so, a waiter is assigned to guide the customer to the table, and the status of the table is changed from "available" to "occupied". After the waiter escorts the customer to the dining table, the waiter asks the customer to show his/her membership card. The waiter can then use an RFID reader on a PDA to access the RFID tag. Therefore, the background, expenditure records and personal preferences of the customer can be retrieved immediately from back-end database, as Fig. 7 shows. The waiter can then provide suggestions and applicable offers to the customer. After confirming the order, a message is immediately transmitted to the kitchen, and all details of the order are shown on the order display system in kitchen. After finishing the meal, the customer can use either cash or an RFID-based membership card to pay the bill, as Fig. 8 shows. For convenience, the system allows the use of PDA for activation of membership card, identify value-added services and checkout. Customers can thus enjoy cash-free convenience.

The amount of e-money, customer background and expenditure records are stored in the back-end database for ease of backup, query and statistical reporting. Customers can also visit the restaurant website and use membership card ID to access the back-end database and retrieve related information. At the counter or dining table, the waiter can also manually look up customer expenditure information, sales ranking of meals and revenue. After checkout, the table status is immediately changed from "occupied" to "available" while awaiting the next customer. Fig. 9 shows a list of forms available on the counter Server. Briefly, the following forms are used.

(1) *Product sales check:* A list of products ranked by popularity is provided, form specified date to the present.

Fig. 8. Checkout function.

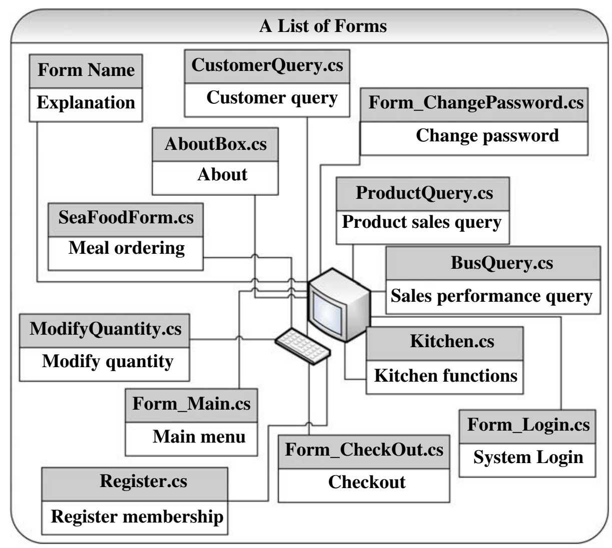

Fig. 9. A list of forms available on the counter Server.

(2) *Customer search:* Operators can use any key term of customers to search for specific customer data. Additionally, past expenditure amounts and preferences can also be retrieved by means of membership card ID.
(3) *Sales performance check:* Historic data, including number of customers and income, can be retrieved.

4.1.4. Implementation of RFID-based value-added and checkout subsystem

Fig. 10 presents the flowchart of RFID valued-added and checkout process. A customer can use either a membership card or cash to pay the check. The membership card checkout process is described as below.

(1) The waiter checks customer password.
(2) The waiter checks customer account balance via the counter Server.
(3) The checkout process will be performed if the account balance is greater than the bill. Otherwise, the checkout process will have to be performed after value-added has been done.

The pseudo codes (Cormen, Leiserson, Rivest, & Stein, 2001) of the main programs of the RFID valued-added/checkout procedures are illustrated as follows.

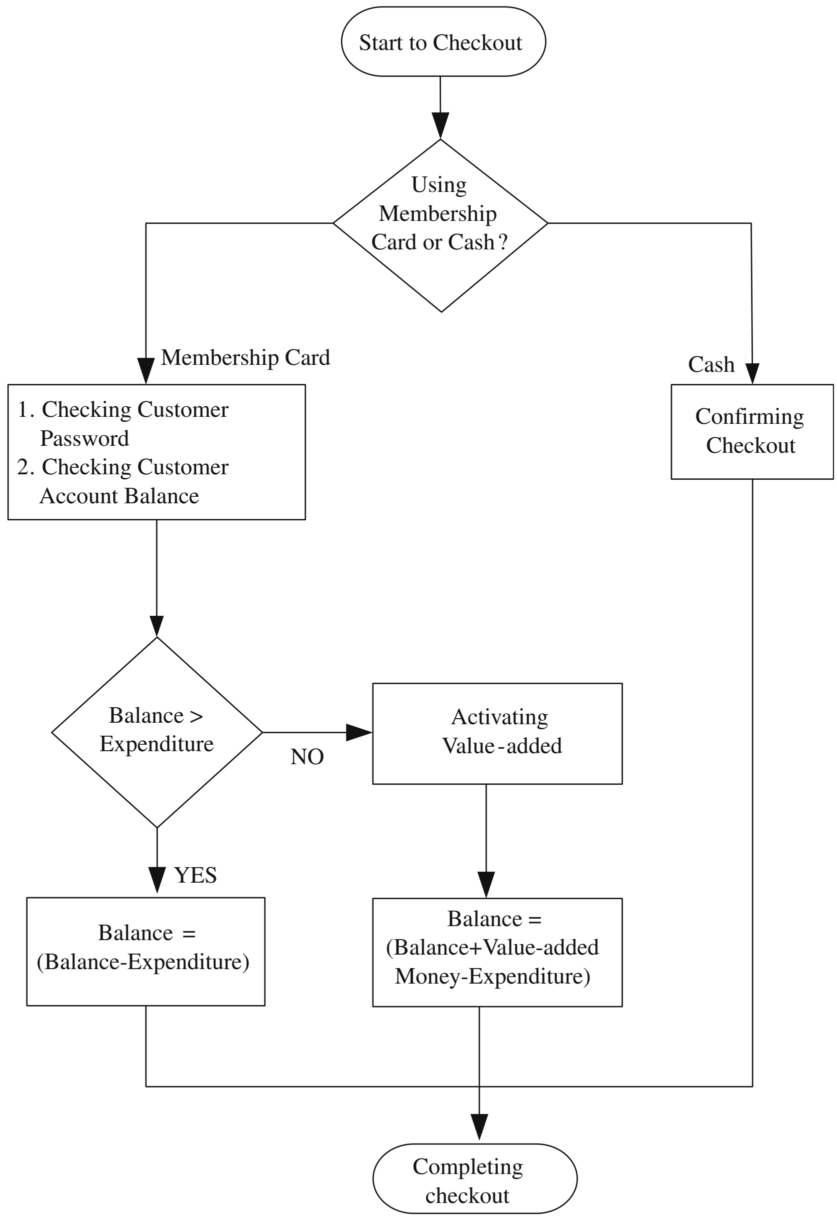

Fig. 10. RFID valued-added/checkout flowchart.

(a) **Checkout**

```
Checkout()
v1 ← get_acc_balance()
v2 ← user_input()
v3 ← v1 – v2
v3_str ← convert_to_str(v3)
// write to tag card
read_block_from_tag()
tag_id, tag_type ← select_tag()
ScanRFIDWriteTag(tag_id, tag_type, v3_str)
```

(b) **Confirm checkout**

```
Confirm_Checkout()
1. Cash Payment
        Checkout()
2. Member Payment
        backend_db ← SqlConnection()
        fSuccess ← check_passwd(backend_db)
        if fSuccess is TRUE
            pay_field ← 1
            return DONE
        else
            pay_field ← 0
            return NOT_COMPLETE
```

(c) **Value-added**

```
Value_Added()
v1 ← get_acc_balance()
v2 ← user_input()
v3 ← v1 + v2
v3_str ← convert_to_str(v3)
// write to tag card
read_block_from_tag()
tag_id, tag_type ← select_tag()
ScanRFIDWriteTag(tag_id, tag_type, v3_str)
```

(d) **Customer Query**

```
Customer_Query()
backend_db ← SqlConnection()
SqlCommand(query_user_cmd, backend_db)
```

query_result ← SqlDataReader(backend_db)
1. Identification
data ← select_user(query_result)
authenticate(data)
2. Expenditure Information
data ← select_expend_info(query_result)

4.1.5. Development of back-end database

The back-end database stores dining table service unit (PDA) access data to reduce the expense of the front-end system and to unify data management. Fig. 11 shows the database structure. The ADO.NET (Active X Data Object Dot Net) library in the .NET Framework allows .NET developers to access the database. The data access procedure requires using SqlConnection to open the database, using SqlCommand to execute SQL commands and using SqlDataReader to read the query results. Fig. 12 illustrates the entire procedure. Fig. 13 shows a list of tables in the back-end database. The following briefly explains the content of Fig. 13.

(1) *Expenditure record:* Records of past customer expenditures can be accessed from the counter Server or PDA.

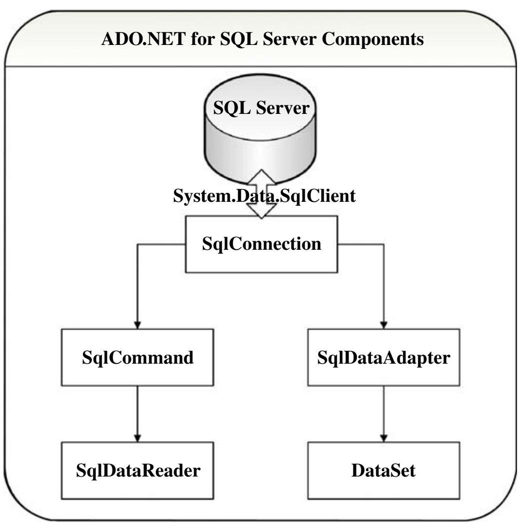

Fig. 11. Database structure.

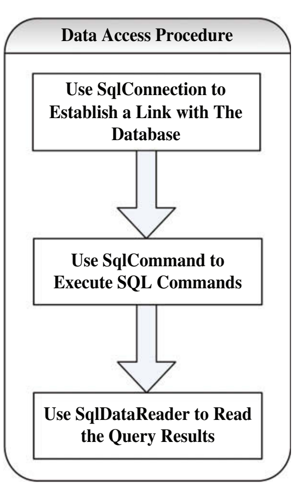

Fig. 12. Data access procedure.

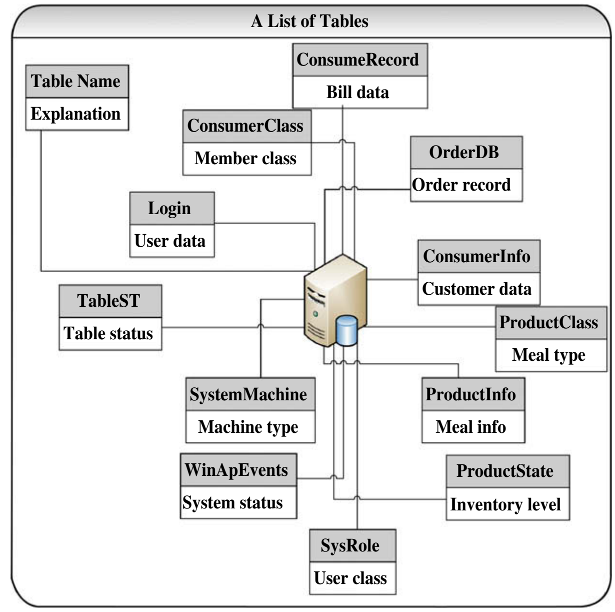

Fig. 13. A list of tables in the back-end database.

(2) *Inventory level:* Updated inventory levels used to predict future demand.
(3) *Meal table status:* Updated real-time meal table.

5. Experimental results

Experiments were performed over a six-month period in two Taipei restaurants: the Just-Win restaurant and Dong-Ya restaurant. A questionnaire was administered to 15 waiters and 45 customers to assess the ease of use (Part A), perceived usefulness (Part B) and attitudes toward the use of the proposed e-restaurant system (Part C). The technology acceptance model (TAM) was employed to measure usefulness and ease of use of the system. The TAM is an information system (IS) that models how users come to accept and use a technology. The TAM posits that two particular beliefs, perceived ease of use and perceived usefulness, are of primary relevance. Perceived ease of use is the degree to which the prospective waiter perceives the IS as easy to use. Perceived usefulness is defined as the subjective belief that the use of a given information system improves waiter working efficiency by using the RFID-related consumer electronic products. The "attitude toward using" is a function of the perceived usefulness and perceived ease of use that directly influences actual usage behavior.

Responses were measured using a 5-point Likert-scale from 1 (strong disagreement) to 5 (strong agreement). Table 1 lists the survey results based on the 5-point scale. In this study, responses to the first item (A1) indicated that most waiters found the e-restaurant system interface to be user-friendly ($m = 4.15$). Responses to the second item (A2) indicated that most waiters believed the e-restaurant system was effective and easy to use for providing customer-centric service ($m = 3.86$). Responses to the third item (B1) indicated that most waiters believed the e-restaurant system could accelerate the service process ($m = 4.22$). Responses to the fourth item (B2) indicated that most waiters thought the e-restaurant system improved working efficiency and service quality ($m = 3.97$). Responses to the fifth item (C1) indicated that most customers enjoyed their dining experience because the customized services offered by the e-restaurant ($m = 4.23$). Responses to the sixth item (C2) indicated that most customers appreciated the real-time ordering and check out services provided by the

Table 1
Statistical results of questionnaire.

Part	Item	Mean	SD
A. Waiter	A1. The interface is user-friendly.	4.15	0.61
	A2. The e-restaurant system has sufficient functions and is easy to operate for customer-centric service.	3.86	0.83
B. Waiter	B1. The e-restaurant system improves the efficiency of the service process.	4.22	0.77
	B2. The e-restaurant system can improve my working efficiency and service quality.	3.97	0.76
C. Customer	C1. I enjoyed my dining time because the e-restaurant system provided customized services.	4.23	0.62
	C2. The e-restaurant system can significantly reduce waiting time because it can provide real-time ordering and check out services.	4.02	0.84
	C3. Adopting RFID technology to immediately identify customers can enhance customer relations.	4.13	0.79
	C4. The RFID-based membership identification service can enhance customer loyalty.	3.76	0.96
	C5. I often receive special meal offer information via e-mail from the e-retaurant system.	3.80	0.82
	C6. I would like to visit the e-restaurant in the future.	3.89	0.83
	C7. I would recommend the e-restaurant system to my friends because of its customer-centric service.	3.78	0.88
	C8. I hope other restaurants also use the e-restaurant system.	3.65	0.98

e-restaurant system ($m = 4.02$). Responses to the seventh item (C3) indicated that customer relations could be significantly enhanced by using RFID technology to immediately identify customers ($m = 4.13$). Responses to the eighth item (C4) indicated that most customers believed that the RFID-based membership identification service would enhance their willingness to visit the e-restaurant ($m = 3.76$). Responses to the ninth item (C5) indicated that most customers appreciated the special meal offer information provided by the e-restaurant system ($m = 3.80$). Responses to the tenth item (C6) indicated that most customers would like to revisit the e-restaurant ($m = 3.89$). Responses to the 11th item (C7) indicated that most customers would like to share the customer-centric service experience with their friends ($m = 3.78$). Responses to the 12th item (C8) indicated that most customers hoped that the e-restaurant system would be used in other restaurants ($m = 3.65$). Figs. 14 and 15 show scenarios in which a waiter is taking order for a customer at the counter and at a dining table.

Two restaurant owners were also interviewed to assess the usefulness and effectiveness of the proposed system. The interview results were as follows.

1. The e-restaurant system can significantly reduce the time needed for training new employees.
2. The e-restaurant system can significantly decrease the probability of human error, thus increasing service quality and reducing running cost.
3. The e-restaurant system can effectively improve the relationship between customers and restaurants.

Fig. 14. The waiter is taking order for the customer at counter.

Fig. 15. The waiter is taking order for the customer at dining table.

6. RFID benefits and challenges: lessons from the case study

The benefits and challenges of the proposed RFID-based e-restaurant system were examined from different perspectives: technological, managerial, and applications. Table 2 presents some of the insights obtained during development of the RFID-based e-restaurant system. The benefits and the main challenges of the RFID-based e-restaurant system are as follows.

6.1. RFID benefits

(i) *Enhancing table and guest management:* Guests can be escorted to proper tables or reserved dining rooms in a quick and friendly manner. Systemizing food and beverage management and standardizing operating processes improve overall restaurant efficiency.
(ii) *Simplifying the billing procedure and improving its accuracy:* Bills can be quickly checked out by using PDA with RFID reader, which improves the efficiency and accuracy of billing procedures.
(iii) *Enhancing inventory and stock management:* Replenishment information generated by the system can be analyzed in order to forecast stock amount of material requirements. The system enables strategic scheduling by chefs and managers in their daily process control.
(iv) *Enhancing customer relationship:* Customer-centric service could efficiently improve customer relationship and approach to the goals of customer satisfaction.

Table 2
RFID benefits and challenges.

RFID benefits	RFID challenges
Technological perspective	
1. Proven technology adopted in food industry	Reliability and stability limitations
2. Responsive multiple tag real-time read/write capabilities	
3. Long read range without specified sight requirement	
4. Normal functioning even in a environments with harsh or very dim lighting	
Managerial perspective	
1. Enhancing table and guest management	Employee retraining
2. Enabling responsive replenishment	
3. Improving dining experience and service satisfaction	
4. Improving efficiency and accuracy of billing process	
Application perspective	
1. Enhancing customer relationship	Customer information
2. Providing inventory level report to manager	
3. Providing replenishment order information for suppliers	
4. Providing real-time ordering information to cooks	
5. Special offer via e-mail	

(v) *Increased product visibility:* The proposed system could efficiently assist suppliers to understand the inventory of food materials, and the inventory information can be used to automatically re-supply food materials to restaurant managers.

6.2. RFID challenges

(i) *Reliability and stability limitations:* The RFID technology is not yet mature. Numerous issues remain to be solved; for example, tags operating on radio frequency may be affected by materials in their close vicinity, signals may be attenuated or detuned by metals or liquids (Leimeister, Leimeister, Knebel, & Krcmar, 2009).

(ii) *Employee retraining:* Using RFID-based systems in traditional restaurants would significantly change service flow and business management. For instance, staff may need a lot of training to familiarize them with the use of e-restaurant technology, which would increase operating costs. Additionally, maintaining the e-restaurant becomes very important for high quality e-service, which also increases business cost.

(iii) *Customer information:* Some customers may not agree to store their preferences and expenditure records on the database due to privacy concerns. Also, some customers may not like to use e-money due to concerns about losing the card.

7. Conclusions

This study has constructed an RFID-based e-restaurant system to support customer-centric service that actively recognizes customers, their preferences and expenditure records. A series of experiments was conducted in two Taipei restaurants, and a questionnaire survey was administered to 15 waiters and 45 customers. Survey results indicated that the RFID technology is effective for providing customer-centric service. Therefore, most of the surveyed customers not only endorsed the use of the proposed system in other restaurants, but also stated that they would recommend the e-restaurant system to their friends. Further, the survey results also indicated that most of the attendants found the proposed e-restaurant system easy to use and useful for improving their working efficiency and service quality. In addition, we also conducted extensive interviews with restaurant owners and the results indicated that the proposed RFID-based e-restaurant system is useful in reducing running cost, enhancing service quality as well as customer relationship.

Notably, security and privacy issues may deter customers from using the RFID-based membership card because current RFID systems fail to adopt strong cryptography simply due to limited resources (Piramuthu, 2008). Specifically, personal privacy and stored e-money may simultaneously be invaded and embezzled when a membership card is lost. To effectively address these issues, only the customer ID is stored in each membership card, and the background, expenditure records, and personal preferences of a customer can be obtained only by authorized personnel via the restaurant database by entering the membership card ID. Further, the amount of e-money of each membership card is limited and is safely stored in counter database, which requires a password for checkout. The proposed e-restaurant system can thus ensure the security and privacy of the membership card.

Developing an artificial intelligence-based (AI-based) e-restaurant system for automatic meal deployment and food material supply-demand analysis based on customer expenditure records is currently underway in our laboratory. Additionally, devising a meal ordering system based on mobile communication technology is also underway.

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