An Interactive RFID-based Multi-touch Product Display System
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ABSTRACT
Multi-touch technology has become more and more popular in recent years. Commercial product display systems are designed straightforward to broadcast the product information to customers. Those systems didn’t provide any interaction function for users, not to mention to record any user interaction behavior. An interactive RFID-based multi-touch system is proposed for product display purpose in which it differs from traditional display systems that it provides interaction for users to adjust the size of object’s images/videos to meet their own preference. Besides, self-organizing map network is used to cluster users’ behavior, and then data mining is applied to discover association rules of users’ behavior. The discovered association rules are then used to recommend related products for users. This paper proposes the methodology of designing a multi-touch display system and provides the experimental results to verify the effectiveness of the proposed work.

Keywords: Multi-touch display system, association rules, human-computer interaction, SOM network, RFID.

1. INTRODUCTION

Radio Frequency Identification (RFID) is a wireless communication technology that has been extensively applied to various fields such as product surveillance, supply chain, automobile parts tracking and telemedicine [13]. RFID technology was originally used during World War II to identify airplanes as friend or foe, but was not highly noticed hereafter for many years. One of the reasons of deterring its applications is the expensive cost of electronic tags. A RFID system is composed of three major components, including reader, tag and middleware. Unlike traditional bar-code system, RFID systems can carry dynamic as well as static data. RFID also provides different specification readers such as LF, HF, UHF for various applications. In this paper UHF RFID reader is used for our product display system.

Most product display systems are designed one-way only to broadcast the product information to customers by far. Those systems didn’t provide any interaction functions for users. Consequently, there is no way to realize users’ browsing behavior.

To enhance the product display systems, both RFID and multi-touch technologies are integrated to provide the interaction between customers and product display system in this paper. Each product is attached a RFID tag as a unique identifier. Whenever a customer intends to browse product information, he/she can take the product to a place that is within the antenna detection range of UHF RFID reader. Then, the product-related information can be automatically displayed on the designated screen. By the designed multi-touch functions, the product image can be enlarged, condensed, dragged or rotated by finger(s). This allows users to view the product from different angles and experience the multi-touch system with joy. Every browsed product tag ID in this proposed display system is recorded in the back-end server for further information processing. Data mining is used to extract association rules from users’ browsing behavior.

In the remainder of this paper, the system overview is discussed in Section 2. In Section 3 the experimental results are given to verify the effectiveness of the proposed system. Finally, conclusions and future work are made in Section 4.

2. SYSTEM OVERVIEW

In this section, we will overview the proposed system from two different angles. One is the hardware configuration that contains three components, UHF RFID module, NFC HF reader, and multi-touch table. UHF RFID module is used to identify products, NFC HF reader is used to login an electronic wallet for users, and the multi-touch table is an interface for users to operate the proposed product display system. The other part is from software viewpoint. Self-organizing map neural network is applied to grouping data. The grouped results are then used in data mining to discover associations among users’ behavior. QR code is designed for users to link to interesting websites or to download the receipt.

Figure 1 shows the structure of the proposed product display system. First, customers use their NFC cards to login to the system. Then, the system will start recording user’s interaction behavior information in server. The user can use the display system and the system will record information about what items the user has browsed, how long the user has interacted with the system, etc. A projector is installed in the system to display browsed objects on wall. If the user decides to buy products, the screen will display a QR code receipt as a record after the user paid the bill. The QR code receipt consists of website link, store information and the total bill.

The flowchart of our system is shown in Figure 2. The system administrator can start the database, UHF RFID reader, NFC module and the product display system. Then, customers can use their NFC card to login and use the functions provided by the proposed display system.
2.1 Hardware Configuration

Figure 3 shows the interior layout of the proposed multi-touch table that contains IR LED, webcam, and UHF RFID reader. UHF RFID module is composed of three components, including reader, tag and middleware. Table 1 lists the hardware specification to design such a system. Each product is attached a RFID tag. When a customer wants to browse the product information, he/she can bring the product to the multi-touch table for browsing the product-related information. The user can dilate, condense, drag or rotate the image/video of the object by his/her finger(s) intuitively. Product-related information includes texts, images, and videos. The system will automatically record how long the user has interacted with the display system and what kind of images/videos the user has browsed. The recorded information will be used for data mining model to discover association among users’ browsing behavior.

Near Field Communication (NFC) [1] is a short-range high frequency wireless communication technology which enables the exchange of data between devices over about a 10cm distance. The technology is a simple extension of the ISO/IEC 14443 proximity-card standard that combines the interface of a smartcard and a reader into a single device. Because the tag’s ID is unique, the NFC module can be used to identify the user. Whenever a user wants to use the product display system, he/she has to take the NFC card to login first. Users can also use the NFC card as their electronic wallets. The type of product information that the user usually browses will be written in the user’s NFC card. This record is different from the UHF RFID module that records how many times the product has been browsed.

The operating interface for the proposed product display system is a multi-touch table [2, 3]. We use the acrylic which acts as a waveguide as the surface of our multi-touch table. Besides, the acrylic is attached with a tracing paper such that IR LED light can scatter uniformly. An infrared projector is installed under...
the acrylic to project the illuminant onto the touch table surface. A webcam attached with a filter is placed at the center of the table under the acrylic. The webcam is used to catch the illuminant of infrared, and the server will determine the position of finger(s) according to the images of the camera’s shot.

Our multi-touch table is based on diffused illumination (DI) principle [4] that has two main forms: front diffused illumination and rear diffused illumination. Figure 4 shows the concept of rear DI technology. Both actually use the same technology. For the front diffused illumination, its light is projected from above the touch surface. When a finger touches the surface of multi-touch table, a shadow is created in the position of the object, and the webcam under the table will sense this shadow. Light of the rear diffused illumination technology is shined at the screen from below the touch surface. While a finger touches the surface, it reflects more light than the diffuser or objects in the background. The extra light is captured by the camera. The proposed multi-touch display system applied the rear diffused illumination technology to implement the multi-touch table. The proposed multi-touch system is shown in Fig. 5.

![Fig. 4. Rear DI schematic.](image)

![Fig. 5. The proposed multi-touch system.](image)

2.2 Software Requirement

Figure 6 shows the homepage of our product display system. There are six buttons on the left hand side and another icon on the right hand side in which different color is used. A pink color indicates that the user has not login and the system cannot be switched on. The color will turn into green following the customer’s login. Each button represents a function. For example, the “introduction” button is used to display price, image, video, and description of the product. “Promotion” button is designed to display the newest promotion to customers. If a customer wants to browse the images or videos of product, he/she can choose “PhotoView” button. User can use his/her fingers to dilate, condense, drag or rotate the images and videos. If a customer chose “Top 5” button, the system will present him/her five today’s most popular products and five most popular products in the system. Customers can also add interesting products to preference list on the pages just mentioned. If a customer wants to look up the products that have been added to preference list, he/she can click the “Order” button.

![Fig. 6. The homepage of our product display system.](image)

The browsing behavior of each user is saved in the back-end server. Data mining technique is applied to discover the association among users’ browsing behavior. The extracted association rules can be used to realize what objects will attract users’ interests to browse. An unsupervised self-organizing map (SOM) network is used to cluster users’ behavior. The SOM architecture is shown in Fig. 7. In order to cluster the data, we need to transform the users’ browsing behavior as an input vector \( x_k = [x_{k1}, x_{k2}, \ldots, x_{km}]^T \) and define a neighborhood function \( \zeta = \exp(-R/2\sigma^2) \) where \( \sigma \) is the neighborhood radius. Figure 8 is the summary of SOM algorithm [5]. The clustered results from SOM network represent how the given patterns distribute over the output space. Each output node acts as a small database that includes the input patterns categorized into the node and the patterns covered by the neighborhood function. This is the idea how we find the association rules from users’ interaction behavior. Besides, using the clustered results from SOM network can expedite finding association rules by data mining model.
In data mining the efficiency to extract interesting patterns from large databases is the main concern. So far many scholars are actively studying how to execute data mining in spatial temporal database to find implicit knowledge. Spatial temporal association rules are extracted from the given browsing behavior database. They present a causality to relate a precedence to a consequence in terms of \( A \Rightarrow B \) \([s, c]\) where \( A \) and \( B \) are set of precedence and consequence items, respectively, \( s \) is the support and \( c \) is the confidence value.

QR code (Quick Response Code) is a kind of two dimensional barcode [11,12]. Unlike the traditional barcodes that provide a limited capacity to write in data, QR codes have much higher storage capacity. Currently, most mobile phones have been installed QR code decoder software or users can download the software free from service providers. The main function of QR code is to reduce troublesome matters that users have to key in texts or websites to the mobile phones. In this paper, QR code is used to produce the electronic receipts that contain the details of product information or the store’s website.

3. EXPERIMENTAL RESULTS AND ANALYSIS

To discover association rules from users’ interaction behavior with the proposed system, several factors are considered in this paper. A membership card issued by the company is itself a RFID card that provides a unique identifier for the system to recognize it. A non-member customer will be issued a temporary RFID card so that every action the user interacts with the system can be also recorded in the back-end server. Only a small portion of users’ behavior is listed here for illustration. Although the size of each to-be-displayed object is carefully tailored to fit the screen size, users may have their own preference to rescale it during browsing. The first factor to be considered is scaling. The second factor is how long a user interacted with the system each time. The third factor is how long a user watched the video presented by the system. All data values are normalized to \([0, 1]\) that are in turn used as the inputs to SOM network for clustering. The grouping results are shown on the rightmost three columns in Table 2. Figures 9 to 11 give the transaction databases for groups 1 to 3 from SOM network, respectively.

![Fig. 7. The architecture of self-organizing map network.](image1)

![Fig. 8. SOM algorithm.](image2)

In this paper, we use spatial temporal data mining model to extract users’ browsing behavior. Temporal data mining, the so-called sequential data mining, uses “time” as a measure criterion. For example, finding out that most of customers will click image B after they click image A, this pattern can be regarded as a sequential pattern. Spatial data mining focuses on discovering the associations among spatial data [9]. It can be used to understand spatial data and explore spatial relationships between spatial and non-spatial data, constructing knowledge base and spatial query optimization, etc [10].

Three algorithms, i.e., AprioriAll [6], AprioriSome, and DynamicSome [7, 8], used for data mining were proposed by Agrawal and Srikant in 1995. There are five main phases in finding the frequent patterns from given databases. First, the records in the database are sorted by primary keys that are the users’ RFID tags in our study. Second, the itemset phase is to find out all high frequency item sets and regard these sets as candidate sequences. Third, the transformation phase is to check whether high frequent item sets are still existed in the customer list database. Fourth, the sequence phase starts from 1-itemset to find all frequent itemset. Last, the maximal phase is to continue the previous step until it cannot find any longer sequence.

<table>
<thead>
<tr>
<th>TID</th>
<th>Scale (%)</th>
<th>Time (System)</th>
<th>Time (Video)</th>
<th>GID(1)</th>
<th>GID(2)</th>
<th>GID(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.45</td>
<td>0.56</td>
<td>0.59</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0.55</td>
<td>0.77</td>
<td>0.52</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0.43</td>
<td>0.91</td>
<td>0.44</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0.21</td>
<td>0.35</td>
<td>0.23</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>0.62</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>0.71</td>
<td>1</td>
<td>0.81</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>0.53</td>
<td>0.79</td>
<td>0.93</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>0.29</td>
<td>0.21</td>
<td>0.37</td>
<td>3</td>
<td>3</td>
<td>1</td>
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<tr>
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<td>0.62</td>
<td>0.73</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>0.91</td>
<td>0.72</td>
<td>0.47</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>
An association rule is interesting if it satisfies the confidence value. For example, R1: IF scale<0.5, then GID=1. Based on the transaction database given in Fig. 8, we can calculate the confidence value for such a rule:

\[
CF(R1) = \frac{|\{ID(2),ID(3),ID(7)\}|}{|\{ID(1),ID(2),ID(3),ID(7)\}|} = \frac{3}{4}
\]

4. CONCLUSIONS AND FUTURE WORK

A novel product display system that integrates RFID, NFC, QR code, and multi-touch technologies is proposed in this paper. Customers can have new browsing or shopping experience through interaction with the proposed system. Users can enlarge, condense, drag or rotate the product images/videos by their finger(s). This allows users to view the product from different angles. The browsed records can be further analyzed to discover informative user behavior. Following the clustering of users’ behavior by SOM neural network, the data mining model is exploited to extract interesting association rules among users’ behavior. A survey is also investigated to realize how joyful the proposed multi-touch product display system is.
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REFERENCES


