RFID based Data Mining for E-logistics

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Abstract: Radio Frequency Identification (RFID) is a useful ICT technology for E-logistics Enterprises. One of the standards used for RFID is Electronic Product Code Information Services (EPCIS). However, it is non-trivial to get effective knowledge from massive data to improve the existed production or logistic system comparing with convenient data collection. In this paper, we develop an intelligent platform which combines RFID for data acquisition, Data Mining for knowledge discovery and enterprise applications in the field of E-logistics. Especially association rule is applied to mine the associations between the distribution nodes and product quality within a product distribution logistic network on the basis of RFID datasets. The analysis result is the same as in the problem hypothesis, which concludes that it will be applicable for such kind of product distribution network analysis.

1 INTRODUCTION

Electronic Logistics (E-logistics) is concerned with the efficient integration of suppliers, factories, warehouses and stores, so that products are distributed to customers in the right quantity and at the right time. Efficient and reliable supply chain is important to trade and industry. The ICT enables significant development of the supply chain. New ICT can change the business process models and can give speed to the growth of the e-logistics. The integration of ICT have become competitive necessities in most industries (Patterson et al., 2003). In recent years, Radio Frequency Identification (RFID) technology has become a mainstream application for handling manufactured goods and materials. As an important driver in today's information-based industries and economics, RFID enables identification from a distance without requiring close-contact as the bar code technology. RFID tags support a larger set of unique IDs than bar codes and can incorporate additional data such as manufacturer, product type, and even measure environmental factors such as temperature. Furthermore, RFID systems can discern many different tags located in the same general area without manual assistance.

RFID technology has been applied to many areas such as supply chain, logistics, libraries and agriculture (Laniel et al., 2008); (Amador et al., 2009); (Abad et al., 2009); (Koutsoumanis et al., 2005); (Emond and Nicometo, 2006). Combining with Data Mining approaches, research fields cover such as object tracking (Cabanes et al., 2008), customer purchasing behaviour analysis (El-Sobky and AbdelAzeim, 2011), supply chain management (Ho et al., 2010) and outlier detection (Masciari, 2011).

In this paper, we develop an intelligent platform which combines RFID for data acquisition, Data Mining for knowledge discovery and enterprise applications in the field of E-logistics and supply chain management. We propose a RFID based logistic network. The RFID data is acquired following to the EPCIS standard, which is fabricated but reasonable. Combining with Data Mining approaches – in this paper the association rule is applied, the relevance between the network nodes and product quality are managed to be deduced by analysing the product flow and the quality.

The paper is organized as the following: Section 1 introduces the features and applications of e-logstics and the importance of integrating RFID technology and Data Mining approaches. Section 2 gives a glimpse of an RFID system briefly. Section 3 introduces the definition and application of Data

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Mining. Section 4 proposes an platform of intelligent integrated RFID system, which consists of 6 levels, and describes each level respectively. Section 5 gives a detailed introduction to a typical Data Mining approach - Association Rules. Section 6 describes a detailed implementation of the intelligent RFID based integrated system. Section 7 comes to the conclusion of the feasibility of the intelligent RFID system.

2 RFID IN E-LOGISTIC

2.1 RFID System

Radio-frequency identification (RFID) is one of numerous technologies grouped under the term of Automatic Identification (Auto ID), such as bar code, magnetic inks, optical character recognition, voice recognition, touch memory, smart cards, biometrics etc. Auto ID technologies are a new way of controlling information and material flow, especially suitable for large production networks (Elisabeth et al., 2006). RFID is a wireless non-contact radio system, which transfers data from a tag attached to an object, for the purposes of identification and tracking. It is a means of identifying a person or object using a radio frequency transmission. The technology can be used to identify, track, sort or detect a wide variety of objects (Lewis, 2004). RFID system can be classified by the working frequency, i.e. Low Frequency (LF), High Frequency (HF), Ultra High Frequency (UHF) and Microwave. Different frequency works for various media, e.g. UHF is not applicable to metal but HF is metal friendly. Thus, the working frequency has to be used on the basis of tracked objects.

Hardware of RFID system includes RFID tag, RFID reader and RFID antenna. RFID tag is an electronic device that can store and transmit data to a reader in a contactless manner using radio waves, which can be read-only or read-write. Tag memory can be factory or field programmed, partitionable, and optionally permanently locked, which enables the users save the customized information in the tag and read it everywhere, or kill the tag when it will not be used anymore. Bytes left unlocked can be rewritten over more than 100,000 times, which achieves a long useful life. Moreover, the tags can be classified by power methods i.e. passive tags without power, semi-passive tags with battery and active tags with battery, processor and i/o ports. The power supply increases the cost of the tag but enhance the readable performance. Furthermore, a middleware is required as a platform for managing acquired RFID data and routing it between tag readers and other enterprise systems. Recently, RFID become more and more interesting technology in many fields such as agriculture, manufacturing and supply chain management.

2.2 The Role of RFID in E-Logistics

Applying RFID technology can lead to large gains in the overall supply chain effectiveness (Agrawal et al., 2009); (Dutta et al., 2007) conclude that RFID integration through E-business architectures provides more benefits than technology integration in current business processes. The roles of RFID in E-logistics include warehouse management, counterfeiting and efficient response to changing demand. (Kärkkäinen, 2003) E-logistics measurement such as store compliance, trend rates, and recovery rates and return inventory turnover can be collected with RFID technology (Payaro, 2004). Since 2006, Airbus has applied RFID to save millions of euros for cutting process cycle times, eliminating paperwork, and reducing inventory (Wasserman, 2007). Zaharudin et al. (2006) indicate that RFID can reduce the bullwhip effect through information sharing between all supply chains. Saygin et al. (2007) suggests that RFID can reduce the bullwhip effect by a better visibility obtained through real-time information of product's locations.

3 DATA MINING (DM)

3.1 Definition

DM is an integration of analysis and modeling technologies developed over the last twenty years. DM is often defined as the process of extracting valid, previous unknown, comprehensible information from large data bases in order to improve and optimize business decision-making process. (Wang, 2007)

Many traditional reporting and query tools and statistical analysis systems use the term "Data Mining" in their product descriptions. It leads to the question, “What is a DM and what isn't?” The ultimate objective of DM is knowledge discovery and DM methodology is a technique to extracts predictive information and knowledge from databases. With such a broad definition, however, an On-line Analytical Processing (OLAP) product or a statistical package could qualify as a DM tool, so some have narrowed the definition. In my option, a DM method should unearth knowledge automatically. By this definition DM is data-driven, whereas by contrast, traditional statistical, OLAP, reporting and query tools are user-driven. It is best to define them as Business Intelligence (BI) tools rather than DM tools.

Using the narrowed definition of DM mentioned above, we would like to follow that DM techniques are at the core of DM process, and can have different functions (tasks) depending on the intended results of the process. In general, DM functions can be divided into two broad categories: discovery DM and predictive DM.

(1). Discovery Data Mining

Discovery Data Mining is applied to a range of techniques, which find patterns inside a dataset without any prior knowledge of what patterns exist. The following examples of functions of discovery Data Mining: (1). Clustering; (2). Link analysis; and (3). Frequency analysis; etc.

(2). Predictive Data Mining

Predictive Data Mining is applied to a range of techniques that find relationships between a specific variable (called the target variable) and the other variables in your data. The following are examples of functions of predictive Data Mining: (1). Classification; (2). Value predication; and (3). Association rules; etc.

3.2 Techniques

This paper will focus on the Associations mining techniques. However, a variety of techniques are available to enable the above functions. Each technique contains numerous algorithms, for example, there are more than 100 different models of Artificial Neural Networks. With systems increasing complexity, it is clear that the DM techniques should be used concurrently rather than separately. (Wang and Wang, 2012) A hybrid DM system in which several techniques with different functions can be integrated to achieve a desired result are often more effective and efficient than a single one. For example, in order to identify the attributes that are significant in a manufacturing process, clustering can be used first to segment the process database into a given predefined number of categorical classes and then classification can be used to determine to which group a new data belongs.

3.3 Procedures

The generic DM procedure from IBM viewpoint (Baragoi et al., 2001) involves seven steps as the following:

1. Defining the business issue in a precise statement,
2. Defining the data model and data requirements,
3. Sourcing data from all available repositories and preparing the data
4. Evaluating the data quality,
5. Choosing the mining function and techniques,
6. Interpreting the results and detecting new information, and
7. Deploying the results and the new knowledge into your business.

To understand how DM can overcome a variety of problems in manufacturing, we consider some activities in a manufacturing company.

4 INTEGRATED RFID SYSTEMS

A RFID system is used to trace and track objects with RFID tags. However, it is far from sufficient to only acquire the RFID data. It will be more valuable to combine an RFID system with Data Mining approaches and construct an intelligent integrated RFID system, with the ability to convert data into knowledge and assist managers to make decisions. The E-business system is designed on the basis of RFID system and introduced in the following sub-sections.

4.1 System Models

The integrated e-business system developed in Knowledge Discovery Laboratory at NTNU is architecturally based on RFID system, decision support system and enterprise applications as shown in Figure 1. The intelligent integrated system consists of 6 levels:

1. Assets level,
2. Data acquisition level,
3. Control level,
4. Database level,
5. Decision support level, and
6. Business Management Level

4.1.1 Assets Level

On the basis of production and logistic system, the assets level of the intelligent integrated RFID system contains products (from materials to finished goods), conveyor belts, machines, pallets, packages and shelves etc.

4.1.2 Data Acquisition Level

The hardware of a RFID system consists of RFID tags, antennas, readers and middleware.

4.1.3 Control Level

A router or switch is used to build up the connection between the devices. A PC is used to configure the equipment at the data acquisition level. During the deployment of the RFID system, the RFID tags are attached to the objects, which are carried by the products or pallets and pass through the conveyor belt, then are packed and stored on the shelves. RFID antennas with various properties are installed respectively at different positions to construct a network of read points. When the object with a RFID tag passes through a read point, it will be detected by the antenna automatically.

4.1.4 Database Model

Thus, as the system runs, the middleware organizes the RFID tag information and forwards it to RFID database. Moreover, the integration of RFID database with other advanced database (e.g. WMS database, MES database and ERP database) is also performed by the middleware.

4.1.5 Decision Support Level

It is vital in the integrated e-business system.

The function of decision support level has beed described in section 3 in detail.

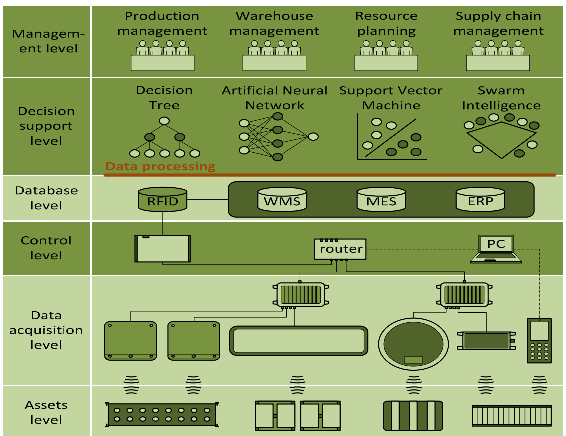

Figure 1: Structure of the intelligent integrated RFID systems.

4.2 EPCIS Standard

Electronic Product Code (EPC) provides a unique, serialized identifier for any kind of object, which is defined in the EPCglobal Tag Data Standard (EPCglobal Inc^{TM}, 2007). Electronic Product Code Information Services (EPCIS) is an EPCglobal standard for sharing EPC related information between trading partners. EPCIS provides important new capabilities to improve efficiency, security, and visibility in the global supply chain, and complements lower level EPCglobal tag, reader, and middleware standards.

```xml
<ObjectEvent>
    <eventTime>2012-02-07T13:23:29.000Z
    </eventTime>
    <recordTime>2012-02-07T12:21:37.000Z
    </recordTime>
    <eventTimeZoneOffset>+01:00
    </eventTimeZoneOffset>
    <epcList>
        <epc>
        urn:epc:id:grai:7071324.0002.11023800029
        </epc>
    </epcList>
    <action>OBSERVE</action>
    <bizStep>urn:epcglobal:cbv:bizstep:shipping
    </bizStep>
    <disposition>
    urn:epcglobal:cbv:disposition:in_transit
    </disposition>
    <readPoint>
        <id>urn:epc:id:sgln:7080000084791.1</id>
    </readPoint>
    <bizLocation>
        <id>urn:epc:id:gln:7080000084791</id>
    </bizLocation>
</ObjectEvent>
```

Figure 2: A section of an XML dataset following the EPCIS.

EPCIS supports a detailed representation of the location and state of material as it moves between organizational boundaries. It provides important business information including the time, location, disposition and business step of each event during an item life, which means 4W – What (product), Where (location), When (time) and Why (business step and status). The information is stored in an XML database.

By gathering datasets during an item in a supply chain and sorting on the basis of EPC and time information, the product flow is able to be extracted for data mining.

5 ASSOCIATION RULES

Association rule is one of the data mining approaches for analysing associations among the items (Han et al., 2012). According to Mild and Reutterer (2003), Boztuğ and Silberhorn (2006) and

Boztuğ & Reutterer (2008), there are two types of association approach; exploratory and explanatory. The exploratory approach aims to uncover and summarise the interrelationships within categories or between items often purchased together (Boztuğ and Reutterer, 2008). Under exploratory approaches, Julander (1992) and Dickinson et al. (1992) used pairwise association measures to identify relationships between item pairs while Agrawal and Srikant (1994), Buechter and Wirth (1998) and Hildermand et al. (1999) discovered association rules between subsets of categories purchased together using data mining technique.

Exploratory approach presents previously undiscovered category relationships in a more aggregate manner, whereas explanatory approach is more targeted, with known variables to be analysed (Mild and Reutterer, 2003). Explanatory approach aims to study the effect of marketing mix and demographic variables on choice across multiple categories (Mild and Reutterer, 2003); (Hoch et al., 1995).

Let $I = \{I_1, I_2, \ldots, I_m\}$ be a set of items. Let D be a set of transactions where each transaction T is a set of items such that $T \subseteq I$. An association rule is an implication of the form $A \Rightarrow B$, where $A \subset I$, $B \subset I$ and $A \cap B = \varnothing$. The rule is evaluated with support value and confidence value. Two measures are usually applied. The support s is the percentage of transactions in D that contain $A \cup B$, which is taken to be the probability $P(A \cup B)$.

$$Support(A \Rightarrow B) = P(A \cup B) = \frac{T(A \cup B)}{D}$$

The confidence c is the percentage of transactions in D containing A that also contains B, which is taken to be conditional probability $P(B|A)$, the relationship between c and s is shown below

$$confindence(A \Rightarrow B) = P(B|A) = \frac{support(A \cup B)}{support(A)}$$

In general, association rule mining consists of two steps:

- Find all frequent itemsets, which will occur at least as frequently as a predetermined minimum support
- Generate strong association rules from the frequent itemsets, which must satisfy minimum support and minimum confidence.

6 IMPLEMENTATION

By analyzing the product flow, potential factors could be referred, which are related to the qualification; meanwhile, possible solutions are also expected to improve the existed logistic network.

6.1 Problem Description

In this paper, a flowchart-like structure is supposed to simulate a product distribution network. Products are distributed to retailers through the designed network, such as milk is delivered to supermarkets from the factory. The supposed distribution network includes 4 layers and 12 nodes totally as shown below.

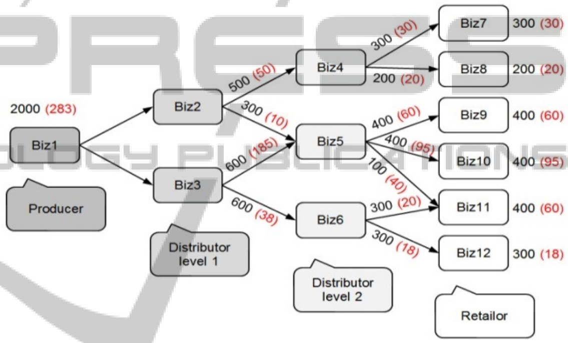

Figure 3: The supposed distribution logistic network.

The 4 layers are respectively the Producer layer, the Distributor level 1, the Distributer level 2 and the Retailer layer. Each layer consists of nodes represented with Biz, which are corresponding to the "business location" in EPCIS. The numbers represent the amount of distributed products in each distribution; moreover, the numbers in parentheses mean the amount of unqualified products included in corresponding branch. In the model design, most unqualified products are delivered through the path which consists of the nodes of Biz1, Biz3, Biz5 and Biz10. The object of the hypothesis is to find the most related nodes in the network if given the product qualification and RFID data of products.

Two reading-points are set at each business location in the middle layers, where one is for the products in while another is for the product out. The time duration is also designed to be independent for each branch in the supposed network, where $T_{\_in}$ means the arrival time of product to the corresponding business location while $T_{\_out}$ means the departure time of the products. In the terminal Retailer layer, only arrival time is considered because we suppose the products are inspected to be bad after the deliveries to the retailers.

Regarding this problem, known parameters consist of the quality of the products when they are delivered to the retailers and RFID datasets recorded at each read point. The RFID datasets are fabricated for the products according to EPCIS standard on the basis of the supposed network. For simplicity, only four keywords of the EPCIS tag are kept, including EventTime, EpcList, ReadPoint and BizLocation as shown in table 1.

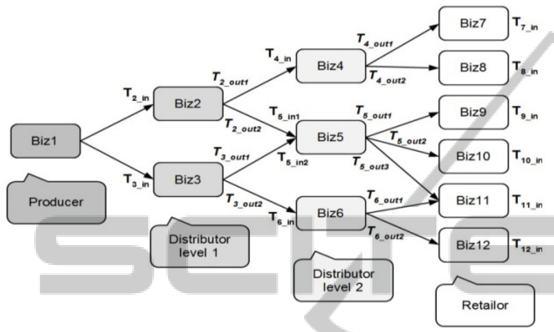

Figure 4: A time-based logistic network as an experimental case.

Supposing that all the RFID datasets are collected from the read points and put together, the delivery path of products are able to be derived according to the parameters of EpcList .

Table 1: The fabricated RFID datasets at one of the readpoints.

EventTime	EpcList	ReadPoint	BizLocation
19.03.2012 09:04	7071371.0001.00000001	7080000000419.1	7080000000419
19.03.2012 09:04	7071371.0001.00000006	7080000000419.1	7080000000419
19.03.2012 09:03	7071371.0001.00000007	7080000000419.1	7080000000419
19.03.2012 09:04	7071371.0001.00000009	7080000000419.1	7080000000419
19.03.2012 09:04	7071371.0001.00000010	7080000000419.1	7080000000419
19.03.2012 09:01	7071371.0001.00000011	7080000000419.1	7080000000419
19.03.2012 09:04	7071371.0001.00000014	7080000000419.1	7080000000419
19.03.2012 09:01	7071371.0001.00000019	7080000000419.1	7080000000419
19.03.2012 09:01	7071371.0001.00000020	7080000000419.1	7080000000419

EventTime, constructing a vector with the form of [EPC, (l_1, t_1), (l_2, t_2),…, (l_k, t_k)], where l_k means the location k and t_k means the time spent on k. The datasets are organized as shown in Table 2.

Table 2: RFID Datasets are organized according to EPCIS keywords.

EpcList	7071371.0001.00000001	7071371.0001.00000002	…
EventTime	19.03.2012 08:02	19.03.2012 08:30	
BizLocation	7080000000418	7080000000418	
EventTime	19.03.2012 09:04	19.03.2012 09:30	
BizLocation	7080000000419	7080000000420	
EventTime	19.03.2012 13:01	19.03.2012 14:34	
BizLocation	7080000000419	7080000000420	
EventTime	19.03.2012 14:32	19.03.2012 16:03	…
BizLocation	7080000000422	7080000000423	
EventTime	19.03.2012 17:01	19.03.2012 18:00	
BizLocation	7080000000422	7080000000423	
EventTime	19.03.2012 18:03	19.03.2012 19:30	
BizLocation	7080000000426	7080000000429	

6.2 Data Preparation and Analysis

As the first step of flow analysis, only the location is considered while the time domain is ignored in this paper. We do the association rule analysis in IBM SPSS Modeler® to find the relevance between the product quality and the business locations, and also the most relevant path in the network. The datasets are organized according to the requirement for the data import of the software, as shown in Table 3.

Table 3: Data preparation for association rule analysis.

EPC	biz1	biz2	biz3	biz4	biz5	biz6	biz7	biz8	biz9	biz10	biz11	biz12	Q
Code 1	T	T	F	F	T	F	F	F	T	F	F	F	F
Code 2	T	F	T	F	F	T	F	F	F	F	F	T	F
Code 3	T	F	T	F	T	F	F	F	F	T	F	F	T

Where T (True) means Event occurs and F (False) means not.

The association rule analysis is performed using the Apriori algorithm in IBM SPSS Modeler®. The model is setup as Figure 5.

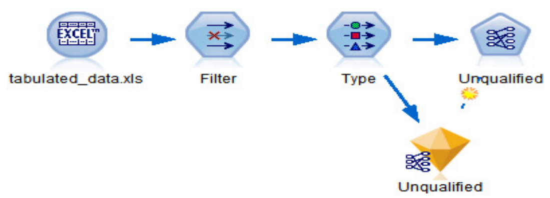

Figure 5: Model setup in IBM SPSS Modeler®.

After the calculation, the relevance between the nodes and the quality is represented by the confidence and rule support, which is listed in Table 4. By sorting the rule support value and confidence value, the importance of the nodes are able to be deduced.

First, we filter the result using a threshold of Rule support value. Supposing that it is set to be 9, only the first 4 rules are included. Then the confidence value is considered, a high value means a strong relevance. Thus, Rule 3 and Rule 4 are the strongest rules with the highest confidence value. Meanwhile, regarding the model design, products of biz3 are all delivered from biz1, so rule 3 is the same as Rule 4. Then the nodes most relevant to the quality defect are founded which includes biz5, biz3 and biz1. On the other hand, the longest rule is the Rule 12 which includes 4 nodes, the same as in the design model. The association rule data mining successfully acquired most relevant nodes and the most relevant path are both deduced the same as the design.

Table 4: Association rules generated.

Rule ID	Antecedent	Confidence %	Rule Support %
1	biz5	21.78	9.80
2	biz5, biz1	21.78	9.80
3	biz5, biz3	30.83	9.25
4	biz5, biz3 and biz1	30.83	9.25
5	biz10	24.00	4.80
6	biz10 and biz5	24.00	4.80
7	biz10 and biz3	24.00	4.80
8	biz10 and biz1	24.00	4.80
9	biz10, biz5 and biz3	24.00	4.80
10	biz10, biz5 and biz1	24.00	4.80
11	biz10, biz3 and biz1	24.00	4.80
12	biz10, biz5, biz3 and biz1	24.00	4.80

7 CONCLUSIONS

In this paper, we develop an intelligent integrated platform for e-business, which consists of 6 levels: 1. Assets level, 2. Data acquisition level, 3. Control level, 4. Database level, 5. Decision support level, and 6. Business Management Level. The main focus of this paper is on (1) RFID system that is used for data acquisition automatically and (2) Data Mining (knowledge discovery) model that is applied for optimizing decision support processes.

An E-logistic network for product distribution is proposed. The RFID data is acquired following to the EPCIS standard, which is fabricated but reasonable. The RFID datasets are generated following EPCIS standard. The product flow is acquired via analyzing the whole datasets. Given the quality of the products, association rule is applied to mining the associations between the distribution nodes and the product quality. After the support and confidence is calculated, the most relevant nodes and path have been deduced, as the description in the problem design. It concludes that association rule mining is applicable to find potential quality related factors within existed logistic network combining with RFID technology. The further research will be done for flow analysis for a real company.

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