Multi-dimensional Anti-counterfeiting Anomaly Monitoring Model Based on RFID in Supply Chain

Meng-jie LUO, Xiao-ming YAO* and Chao-ran LI

School of computer and Cyberspace Security, Hainan University, Haikou, Hainan Province, China

Keywords: RFID, Supply chain, Complex event processing, Anti-counterfeiting, Anomaly detection.

Abstract. There are two kinds of abnormal conditions in the RFID-enabled supply chain such as forgery and miss operation, but the existing anti-counterfeiting model is not used to distinguish them. In this regard, based on the definition of abnormal activity and its dependencies, this paper proposes the abnormality detection rules of the “frequent pattern” yielded by big data techniques. From a multi-dimensional perspective, combined with EPC data and prior information sent from the previous nodes, it can effectively distinguish between forgery activities and operational anomalies. Consequently, a secure visualization system for anti-counterfeiting and anomaly monitoring in rfid-enabled supply chain is implemented with satisfactory results.

Introduction

RFID is a kind of Radio-Frequency-Identification-Technology. The system processes the collected data form an electronic pedigree (e-pedigree) that records the trajectory of the goods, thereby realizing traceability tracking of the goods [1]. Through the systematic retrospective analysis of the electronic pedigree, the supply chain anomaly can be detected and monitored to achieve the purpose of screening for counterfeit and shoddy goods.

In real life, RFID anomalies can be divided into non-forgery activity anomalies and counterfeiting activity anomalies. Non-forgery activities are mainly caused by abnormal weather, personnel misoperation or machine missed inspection. The abnormality of counterfeiting activities is mainly caused by forgery or cloning of RFID tags. Timely detection of abnormal information and classification can effectively correct non-forgery anomalies and eliminate forgery anomalies. For the anomaly classification and its dependencies, the literature [2] made a series of analyses.

In addition, in order to achieve the purpose of detecting abnormalities in the system layer, many scholars at home and abroad have proposed corresponding detection models. Jin Guoping [3] used discrete Fourier transform to compare the similarity of path sequence structure to detect distance anomaly, and used the analysis rules between nodes to detect the circulation efficiency and abnormal conditions of the supply chain. HoSung Le et al. [4] proposed a frequent pattern mining algorithm for finding legal supply chain patterns from tracking records. Through computer simulation, the algorithm was used to model the flow of authentic products in the integrated supply chain. Backtracking. Hariharan et al. [5] established a partially observable Markov decision process model for radio frequency identification directed search. The above research methods start from a single-dimensional perspective, resulting in insufficient data for comprehensive analysis; and the above model only filters data information that may have problems, and does not classify it, and thus cannot effectively integrate information.

Aiming at the defects of existing analysis models, such as single analysis dimension, insufficient data volume and inability to distinguish non-forgery anomalies, this paper proposes a multi-dimensional RFID supply chain anomaly anti-counterfeiting model, from historical sources, quantity of scale, location changes, inventory time, etc. From a multi-dimensional perspective, combined with EPC data and early submission information, the logistics is tested based on a large number of experimental data, and the universal anti-counterfeiting rules are obtained.
Methodology

According to the detection rules obtained by the above analysis, the system is divided into four modules, which are data acquisition module, data storage module, data analysis module and data display module.

A. Data acquisition module

The data acquisition module obtains a large amount of actual logistics data by crawling the information of the logistics website as a sample of system analysis and research.

B. Data storage module

The data storage module normalizes the acquired logistics information to ensure that its data attributes are completed, which is convenient for summarizing the rules.

Each time the goods arrive and exit, the site will provide corresponding information and record it in the EPCGlobal network database for all sites to query. The EPCglobal-RFID architecture framework defines the main facility component interface standards for collecting and recording EPC data, thus allowing individual sites to use interoperable components to build their internal systems [7]. The adjacent sites can be verified by ASN. The ASN, the Advanced Shipping Note, is a detailed list of goods that are delivered in advance using an electronic communication network at the time of shipment. This allows you to check the order quantity, order time, and logistics status to detect fake and shoddy anomalies. In the analysis and analysis, for the convenience of description, the \(<id, p, t> \) triplet can be used to describe the individual cargo information on the site [8]. The id is the unique identification code of the goods label, p indicates the location of the goods, and t indicates the current time stamp. For group goods, it can be described using a collection of triples of site goods.

C. Data analysis module

The data analysis module uses the anti-counterfeiting detection model of this paper to analyze the data, detect forged data and non-forgery abnormalities and store them.

The abnormal behavior of logistics can be divided into forged abnormalities and non-forgery abnormalities. After analysis, we can summarize the following detection rule model.

1. Consistency of historical sources.

The receiving source of the site should exist in a closed collection of historical sources.

2. The partial routes of goods with similar properties should be approximately the same.

In the RFID supply chain system, affected by the turnaround time constraints, the site will ensure that the transportation path tends to be consistent as much as possible, which will help management. And if there is a deviation in location change, it is often due to abnormal activities.

3. Goods with similar attributes should be stored at approximately equal time at the site.

In the supply chain, items generally need to be delivered to their destinations as quickly as possible, thereby reducing the shelf life of the items, thus requiring maximum residence time in the warehouse.

4. Consistency of quantity and scale.

The site carries out frequent shipments and inbound operations at all times, directly related to the number of inbound and outbound goods, and the amount of single inbound or outbound cargo does not constitute a test standard, and two states are required. Combined with the inventory of the site, the conclusion that the quantity of all goods at the site should satisfy the certain operational relationship is that the amount of inbound cargo in a certain period of time should be equal to the amount of cargo in the inbound state and the amount of outbound cargo in the time period.

5. Uniqueness constraint rules
At any time, it is determined that the goods EPC in the supply chain is necessarily unique, so the goods Id in the EPCGlobal can be checked during the detected time period, and if the same record is detected, there must be a forgery abnormality.

(6) Advance information consistency constraint rules

The rule mainly detects the quantity anomaly: firstly, if the information from the previous node is reliable, the detection error including the detection error from the RFID card reader and the number of cloned goods may be detected, and the detection result may need to be combined with the node. The results of multiple internal links are comprehensively determined.

D. Data display module

The data display module adopts the MVC structure and encodes in Java, and displays the abnormal results obtained after the system analyzes the logistics data.

Result

According to the above system design, the RFID-based security visualization system is finally realized. The system is mainly for the supply chain sites, its function is to analyze the site for each site may exist abnormal logistics information, such as time abnormal logistics, location abnormal logistics, stay time abnormal logistics and the site of the volume of goods abnormal. Specific can be divided into site information overview module, logistics data statistics module and logistics flow path analysis module.

According to the design of this article, the RFID logistics abnormality monitoring system was finally completed. As shown in Figure 1.

![Figure 1. RFID logistics abnormality monitoring system.](image)

First of all, through the RFID logistics abnormality monitoring system designed and implemented in this article, the cumulative total amount of logistics and the cumulative total amount of abnormal logistics at this site can be clearly obtained. For real-time monitoring, it is possible to obtain the real-time inventory flow, out-flow inventory, inventory flow and average staying time in real time. At the same time, the data statistics are also given in the form of bar graphs. In the real-time monitoring chart of logistics transportation at this site, the orange origin represents the subsequent site of the logistics sent from this site, while the number represents the abnormal logistics volume in the logistics arriving at this site. According to the historical abnormal logistics detection amount, the reliability of the next site can be known in detail. When the logistics is sent to the site with lower reliability, it needs to be monitored more strictly.
Secondly, based on the logistics inventory information, the average length of stay of the logistics, and the logistics transportation distance, the abnormal logistics information of the day can be analyzed, and then the specific proportion of abnormal logistics types can be obtained. The abnormal detection results of the number and time of the stations can be obtained through the relationship between the average stay time of the logistics and the quantity of goods in and out of the stations. The abnormal logistics information can be obtained by comparing with the standard value.

Finally, this system records all logistics information from the perspective of site history, current month's logistics records, this week's logistics records, and current day's logistics records, and gives them in the form of tables.

Through the RFID logistics anomaly monitoring system proposed in this paper, from the perspective of time, place and the amount of goods in and out, we can get all kinds of logistics data statistics of the scene clearly, and analyze the logistics anomaly on the scene in real time, so as to greatly improve the security of the scene.

Summary
In this paper, the existing anti-counterfeiting model detects the shortcomings of single dimension, insufficient data volume and difficulty in distinguishing non-forgery abnormal data. Based on big data, it combines EPC data from multi-dimensional perspectives such as historical source, quantity, location change and inventory time. And report the information in advance, analyze the abnormal detection rules, and build a multi-dimensional anti-counterfeiting anomaly monitoring model based on RFID in the above-mentioned rules. The final experimental test proves that the model can effectively detect non-forgery anomalies, and the detection process is more stable and reliable than the existing models.

During the experiment, it was found that some of the forged data also had the abnormal characteristics of the non-falsified data, thus reducing the accuracy of the classification result. In the future work, the two abnormal dependence factors will be further analyzed, and the classification rules will be expanded to improve the accuracy of the detection.

Acknowledgement
This project is supported by the National Natural Science Foundation of China under grant 61462023

References
[1] Staake T, Thiesse F, Fleisch E. Extending the EPC network: the potential of RFID in anti-counterfeiting.[J]. 2005:1607-1612.
[2] Yao X, Zhou X, Ma J. Logistics Exceptions Monitoring for Anti-counterfeiting in RFID-Enabled Supply Chains[C]//Future of Information and Communication Conference. Springer, Cham, 2018.
[3] Kamaludin H, Mahdin H, Abawajy J H. Clone tag detection in distributed RFID systems[J]. 2018, 13(3):e0193951.
[4] Lee C, Cho C, Ryoo J, et al. Planar near-field RFID reader antenna using opposite-directed currents[C]//IEEE International Workshop on Antenna Technology. IEEE, 2009.
[5] Hariharan S, Bukkapatnam S T S. Misplaced item search in a warehouse using an RFID-based partially observable Markov decision process (POMDP) model[C]//IEEE International Conference on Automation Science & Engineering. IEEE, 2009.
[6] Cheung, HH, Choi, SH. Implementation issues in RFID-based anti-counterfeiting systems[J]. Computers in Industry, 2011, 62(7):708-718.

[7] Amin Rida, Rushi Vyas, Terence Wu. Development and Implementation of Novel UHF Paper-Based RFID Designs for Anti-counterfeiting and Security Applications[C]// Anti-counterfeiting, Security, Identification, 2007 IEEE International Workshop on. IEEE, 2007.

[8] Yao X, Zhou X, Ma J. Object event visibility for anti-counterfeiting in RFID-enabled product supply chains[C]// Science & Information Conference. IEEE, 2015.