RFID Based Real-Time Manufacturing Information Perception and Processing

Wei Song, Wenfeng Li, Xiuwen Fu, Yulian Cao, and Lin Yang

School of Logistics Engineering, Wuhan University of Technology, Wuhan, P.R. China
songwei28@163.com, {liwf,XiuwenFu}@whut.edu.cn,
yulian@uw.edu, gnwd@msn.com

Abstract. Timeliness, accuracy and effectiveness of manufacturing information in manufacturing and business process management have become important factors of constraint to business growth. Single RFID (Radio Frequency Identification) technology with uncertainty will cause great difficulties for application systems. This paper mainly focuses on the process of manufacturing information, real-time information perception and processing problems. It achieves real-time manufacturing information acquisition and processing by combining RFID and sensor technology, which uses Complex Event Processing (CEP) mechanism to realize sensor and RFID data fusion. First of all, the event processing framework which is from the perspective of the integration of sensors and RFID is given. Then, real-time acquisition and intelligent information processing models were introduced, including primitive event handling and complex event processing method. Finally, the practicality of our method was verified through applying it to a mold manufacturing enterprise management field.

Keywords: Manufacturing information, real-time data processing, RFID, CEP, Internet of Things.

1 Introduction

With the rapid development of information technology, sensor technology and communication technology, timeliness, accuracy and validity of manufacturing information in manufacturing and business process management have become important factors of constraint to business growth, which have caught much closer attention. In recent years, the flow characterization, storage and optimized control to production process of real time material flow, process flow and control flow has gradually become a central feature of intelligent manufacturing [1]. Manufacturing company's existing information system has greatly improved the operational efficiency of enterprises, but there is a certain lack of automated, real-time and accuracy.

RFID as an advanced automatic identification technology has received widespread concern from industry field, which is widely used in all aspects of manufacturing in recent years. The characteristics of real-time identification, accurate and long distance reading from RFID make it possible to collect real-time manufacturing information

J. Kołodziej et al. (Eds.): ICA3PP 2013, Part II, LNCS 8286, pp. 303–310, 2013.

accurately [2]. Because of RFID wireless communication features and manufacturing complexity of the system environment, the single RFID technology with uncertainty will cause great difficulties to the application system. The uncertainty of RFID data is mainly reflected in the following points.

1) Rereading: In order to cover a certain reading area, RFID reader antenna's reading power is set to be larger, making the object affixed with RFID tags repeatedly been recognized when pass by a reader coverage area, resulting in a large number of redundant, ineffective RFID data.

2) Data missing: When a tagged object go through the reader reading range, due to interference between objects blocking or other reasons, the reader does not read the label. Such information is lost so that the target cannot be correctly identified.

3) Over reading: When a tagged object has not gone through a RFID reader, due to reflection or reader antenna power's large setting, the object might be recognized by reader and will record this event which actually did not occur.

4) Misreading: RFID data read need several electromagnetic conversions and need to transfer out the acquired data through communication interface. Error exists in both the process of decoding and transmission, making the reader collected data with the label sent back data inconsistencies, causing data errors, or garbled.

In order to solve above problems, this paper will combine sensors with RFID and use CEP mechanism on the sensor and RFID data fusion to reduce uncertainty in the data, which can help realizing real-time collection and processing of manufacturing information. Firstly, framework for event processing is given from the perspective of the sensor and RFID integration. Then, the introduction of intelligent real-time information collection and processing models were given followed, including primitive event processing and complex event processing method. Finally, the practicality of this method was verified by applying it to the mold management of a manufacturing enterprise.

2 Related Works

Currently, in the manufacturing enterprise production information management and real-time data process, domestic and foreign scholars have done a lot of research and gained a relatively abundant research results. Patrik Spiess[3], Sun Zhengwu[4] and Shen Bin [5] have studied application framework and service model of Internet of Things(IoT) technology applied in industry, which provide a reference for IoT application. However, they haven't investigated the use of real-time data acquisition and processing. Francesco Aiello[6] present the MAPS to realize the real-time human activity monitoring, provide a reference for real-time information processing in manufacturing environment.The method of extracting useful data from large amounts of data and analyze correlation between data is top priority of IoT applications in manufacturing, which is able to help enterprise make respond to these key information critical and timely.

Complex event processing is performed by David Luckham at Stanford University [7]. CEP matches events sequence that meet event definition based on event attributes from the event stream according. The basic idea of complex event processing is as follows. 1) Abstracting original event from large amount of data. These events can be changes in the state, the implementation of activities, etc., can also be a user or the system concerned information. 2) Through a certain event operator to correlate different events form a composite event, which means a new meaning and reveals hidden information between data. 3) It obtains causal relationship and hierarchical relationships between events through the event handling. Causality can help users analyze the nature causes of the system macroscopic phenomena, and hierarchical relationships can provide users of different areas and different levels with personalized event information, improving enterprises' response ability.

CEP mechanism is effective means to deal with the uncertainty of RFID data, which has received widespread concern from research scholars. Wang Fusheng [8] used directed graph in the RFID event flow for complex event processing. Zang Chuanzhen [9] proposed real-time enterprise architecture based on intelligent objects, giving the event's basic concepts, time model, and hierarchical model. Jin Xingyi [10] used timed Petri nets (TPN) in RFID complex event to detect data stream, which provided a theoretical support and reference for this study. With further research, there are some CEP prototype system for RFID applications, such as SASE [11], Cayuga [12] and ZStream [13] and so on. These systems are mainly for complex event processing systems on real-time data streams RFID applications, which provide the basic functions of complex event processing, but did not consider the uncertainty of the input RFID data stream, also did not consider the environmental complexity of the manufacturing site and process correlation of applied aspects.

3 Real-Time Data Collect and Process Model

An event can be defined as a record of an activity in a system for the purpose of computer processing [7], or an occurrence of interest in time [8].

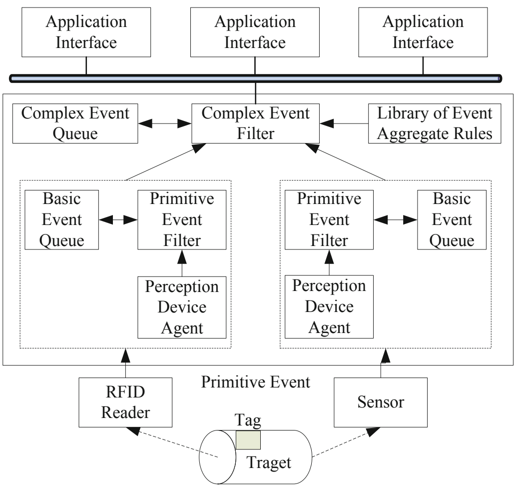

Fig. 1. Data collect and process model

In general, events can be categorized into primitive event and complex event. A primitive event occurs at a point in time, while a complex event is a pattern of primitive events and happens over a period of time. Considering multi-tag, multi-reader, multi-sensor manufacturing information environment, we propose a hierarchical data acquisition and processing model, shown in Figure 1.

First, perception device Agent collect data from reader or sensor and generate primitive event, then upload it to primitive event filter. Primitive event filter clean the redundant event based on primitive event filter rules, and put the filtered event into basic event queue. Complex event filter aggregates basic events into complex based on complex event aggregation rules, then put it into the complex event queue. The application system can easily get an appropriate complex event from the application interface.

3.1 Primitive Event Process

When the physical objects installed with RFID tags crosses through the RFID reader, the phenomenon such as tag *re-reading* and *misreading* will create a huge amount of redundant data. The layer of Primitive event process will clean the redundant data created by tag re-reading and misreading according to the content of tag and tag objects. Given the circumstance of multi-tags reading, the algorithm of primitive events process is designed. The algorithm can be divided into 2 steps, the first step is to acquire the primitive events from agent of equipment resources, filter the redundant or error data and then store the post-filter data into queue of basic events. The task of step 2 is to filter the timeout data from queue of basic events.

Algorithm 1: Primitive Event Filter

Step1: read a primitive event *Ep1*
Step2: **if** the *Ep1* is not exist in *Primitive Event Queue*
  turn Step4
Step3: **if** *Ep1.TimeStamp* is timeout
  turn Step6
Step4: **if** the *Es1* is error
  turn Step6
Step5: put *Ep1* into *Primitive Event Queue*
  end this primitive event process
Step6: abandon *Ep1*
  end this primitive event process

Algorithm 2: Primitive Event Queue Filter

Step1:**for**(i=queue_min; i<queue_max; i++)
Step2: read primitive event *Epi* from *Primitive Event Queue*
  if *Epi.TimeStamp* is timeout
    delete *Epi*
    i++
    turn Step2
  else
    queue_min = i
    turn Step3
Step3: end this primitive event queue filter

Fig. 2. Primitive event process algorithm

The algorithm 1 can only be triggered. When perception device Agent finishes the reading of one primitive event, the algorithm 1 is triggered. If the event has already listed in the queue of basic event, the time stamp of the event will be acquired. If the difference between newly time stamp and already-existed stamp is lower than the pre-configured threshold, here we can consider the newly coming event as the false redundant event and delete it correspondingly. If the events don't exist in the queue of basic events, we can take the event as the newly coming event. Next, the procedure comes into the stage of fault tolerance.

The sensing equipment should be fault-tolerant among when collecting and delivering data. Before judgment, the error data should be filtered. Due to the variety of sensor data, the fault tolerance should be determined according to the variety of situation. In the scene of manufacturing, each tag has its own physical meaning. According to the corresponding relationship between tag and objects, we can find out whether the physical meaning of the tag is listed in the mapping list. If the physical meaning of the tag fails to find, we can consider the data is error data. If the relation is established, the data is listed in the queue of the basic events and the primitive event process is completed.

The manufacturing scene has strict request for real-time data sampling and processing. Aiming to guarantee the timeliness, we need to establish the filter mechanism to filter the timeout redundant data from the queue of the basic events. The algorithm 2 is based on this idea.

3.2 Complex Event Process

Although the layer of primitive events process is able to filter the redundant or error events and guarantee the real-time of perception device, the *misreading* and *over reading* fail to disposed. According to the various request of different steps in manufacturing scene, we need to fuse the events from different equipment to meet the disposal request of the above layer. The complex events reflect the group of the events following certain rules.

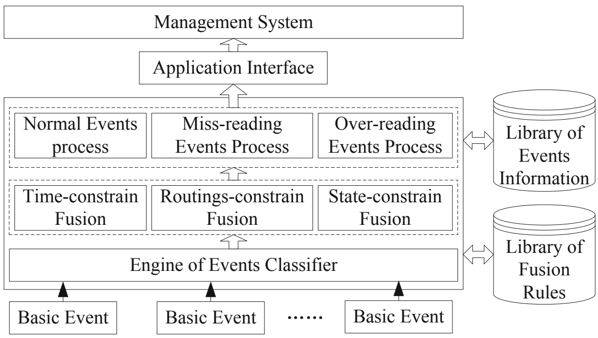

Fig. 3. Architecture of the complex events disposal

According to the fusion methods of the events, the events includes: complex events fusion based on time-constrain, complex events fusion based on routings-constrain and complex events fusion based on states-constrain.

The complex events fusion based on time-constrain: the events are closely time-related. The events always happen at the same time or not happen in certain period.

The complex event fusion based on routings-constrain: the sensing object is closely related to its location. According to the information of the location, the order of the events happening can be determined.

Complex event fusion based on states-constrain: the event happening is closely related to the state of the objects. Only in the certain states, the sensing events are able to happen.

Based on the proposed rules, architecture of the complex events disposal is designed in this section (figure 3).The goal of library of fusion rules are to store the relevant fusion rules and conditions in terms of the application requirement; the library of events information is to store the complex events and related process consequences; the engine of events classifier is to access the simple events from the layer of primitive event process and classify the uploaded basic events according to the fusion rules. The responsibility of processor of abnormal event is to detect the abnormal event and then deal with the abnormal events. The processor of abnormal events makes reasonable judgments based on the library of fusion rules. When detect the over-reading events, the redundant events will be deleted and this behavior will be stored into the library of events information. When detect the miss-reading events, the redundant events will be complemented and this behavior will be stored into the library of events information. When deal with the normal events, the record of normal events will be added into the library of events information. The application interface is to provide query interface and call interface for the backstage management system.

4 Case Study

To testify the proposed method of the real-time sensing and information processing, the related test in a discrete manufacturing enterprise is carried on.

Table 1. Statistics table of production

Collection point		NPE	NBE	NCE	CT	NSR	RRE
Entry and exit of the workshop	R1	753	62	55	55	55	0
	S1	68325	68325				
	R2	986	121				
	S2	12961	12961				
No.3 door	R3	5923	528	401	368	368	9%
	S3	1235	1235				
No.4 door	R4	652	48	30	27	27	11%
	S4	2358	2358				

The statistics of a certain month in the workshop is shown in table 1. R1 is the fixed RFID reader located in the NO.1 door. S1 is the infra sensor installed nearby the NO.1 door. In table 1, the NPE represent the number of primitive events, the NBE represent the number of basic events. The number of complicated events (NCE) is the amount of the complicated events fused by data flow. The circulation times (CT) is the real circulation times of the molds. The number of the system recognition (NSR) indicates the circulation time of the molds though judgments by complicated events. The rate of the redundant event recognition (RRE) is the proportion of the non-effective events in the complex events auto-recognized by the system.

From table 1, we can conclude:

1）Through filtering the primitive events, amount of the redundant data is able to decrease significantly. Take entry R3 as an example, the simple events accessed in the mouth is 5923. After filtering, the number decreased to 528. The data amount has been decreased by 90%.

2）The introduction of the sensors also contributes to the accuracy of the event disposal. Take door 3 as an example, the subsequent events has been decreased by 32% ;

3）Deployment of promising mounts of sampling sites and making reasonable fusion rules are able to enhance the recognition rate of the effective events. The entry and exit of the workshop both deployed 4 sampling sites respectively. The redundant rate is zero. For No.3 and 4 doors, as the sampling sites are only 2, the redundant rate is 10%.

4）Through combining the actual production procedures, the recognition of the system rate can be improved effectively. Through data matching between recognized events and mold usage plan, the redundant events can be filtered.

Form the application results we can conclude that, the proposed method, combined with sensor and RFID can effectively improve the efficiency of complex event processing in manufacturing environment, combined with production process and complex event process mechanism can effectively eliminate redundancy event and increase system recognition rate. It also demonstrated that the proposed method is practical and feasible.

5 Conclusion

In this paper, through application of RFID and sensing technologies and building disposal mechanism of complex events, the uncertainty of the data can be lowered and the timeliness and accuracy of the data processing can be achieved. Firstly, our work is to give an architecture of the real-time information processing. And then, the disposal methods are analyzed in details about primitive event process and complex event process. Finally, the practical application in manufacturing testifies the availability and practicability of the proposed method.

The application of the disposal method of the complex events is able to enhance the accuracy of the system. The making of cohesion rules is closely related to manufacturing procedures. In the future work, we will continue the research on the process of the event cohesion, enhance the cohesion efficiency and further enhance the information level of the manufacturing industry.

Acknowledgment. This research is partly supported by National Key Technology R&D program (2012BAJ05B07), Key Project of Natural Science Foundation of Hubei Province (2010CDA022), Science and Technology Project of Guangdong Province (2010A080408011) and the modern information service special funds competitive distribution project in Dongguan City (DG201007).

References

1. Vlad, M.S., Valentin, S.: A RFID system designed for intelligent manufacturing process. WSEAS Transactions on Information Science and Applications, 36–41 (2007)
2. Atzori, L., Iera, A., Morabito, G.: The Internet of Things: A survey. Computer Networks 15, 2787–2805 (2010)
3. Spiess, P., Karnouskos, S., Guinard, D., et al.: SOA-based integration of the internet of things in enterprise services. In: Proceedings of IEEE ICWS 2009, Los Angeles, CA, USA, pp. 968–975 (2009)
4. Sun, Z.W., Li, W.F., Song, W., et al.: Research on manufacturing supply chain information platform architecture based on Internet of Things. Advanced Materials Research, 314-316, 2344-2347 (2011)
5. Shen, B., Zhang, G.Q., Wang, S.L., et al.: The Development of Management System for Building Equipment Internet of Things. In: 2011 IEEE 3rd International Conference on Communication Software and Networks, pp. 423–427 (2011)
6. Aiello, F., Fortino, G., Gravina, R., et al.: A java-based agent platform for programming wireless sensor networks. The Computer Journal 54(3), 439–454 (2011)
7. Luckham, D.C.: The power of events: an introduction to complex event processing in distributed enterprise systems. Addison-Wesley (2002)
8. Wang, F.S., Liu, S.R., Liu, P.Y.: Complex RFID event processing. The International Journal on Very Large Data Bases 18(4), 913–931 (2009)
9. Zang, C.Z., Fan, Y.: Complex event processing in enterprise information systems based on RFID. Enterprise Information Systems 1, 13–23 (2007)
10. Jin, X.Y., Kong, N.: Efficient complex event processing over RFID data stream. In: The 7th IEEE International Conference on Computer and Information Science in Conjunction with 2nd IEEE International Workshop on e-Activity, Portland, pp. 75–81 (2008)
11. Wu, E., Diao, Y., Rizvi, S.: High-performance complex event processing over streams. In: Proceedings of the 2006 ACM SIGMOD International Conference on Management of Data, Chicago, USA, pp. 407–418 (2006)
12. Mei, Y., Madden, S.: ZStream: A cost-based query process or for adaptively detecting composite events. In: Proceedings of the 35th SIGMOD International Conference on Management of Data, Providence, USA, pp. 193–206 (2009)
13. Brenna, L., Alan, D., Johannes, G., et al.: A high-performance event processing engine. In: Proceedings of the 2007 ACM SIGMOD International Conference on Management of Data, Beijing, China, pp. 1100–1102 (2007)
14. Yao, W., Chu, C.H., Li, Z.: Leveraging complex event processing for smart hospitals using RFID. Journal of Network and Computer Applications, 799–810 (2011)