A Complex Event Detection Method formulti-probability RFID Event Stream

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***Abstract*—Aiming to solve the problems of big combination number of possible events and high memory consumption and low detection efficiency during the detection process of Naive method for multi-probability RFID event streams, a new complex event detection method based on NFA-DAG (Nondeterministic Finite Automaton-Directed Acyclic Graph) is presented for multi-probability RFID event stream in this paper. The achievement of our proposed algorithm lies that we use the union of NFA and DAG to detect multiple-probability RFID event stream, as a result, it can effectively improve those problems above existed in Naive method. The simulation results show that our proposed scheme based on NFA-DAG in this paper can greatly reduce the combinations number of possible events, lower memory consumption and improve event detection efficiency in detecting multi-probability RFID event streams compared with Naive method, without degrading detection quality.**

***Index Terms*—Complex event detection; Multi-probability; RFID event stream; NFA; DAG**

I. INTRODUCTION

RFID (Radio frequency identification) technology is a non-contact automatic identification technology based on RF communication and it has been widely used in various aspects of our life. Since it is vulnerable to the impact and interference of environmental, leakage read, dirty read and more read by its own RFID reader, as well as subjective uncertainty caused by RFID data processing, therefore, it results in lots of uncertainty in the entire life cycle of RFID application. Uncertainty has become a very general and important feature for RFID data. With the increasingly wide applications of RFID technology, RFID event detection technology with uncertainty, especially RFID complex event detection technology with uncertainty, raises a strong interest study in the academia and industry.

Although some traditional complex event detection and processing systems, such as SASE[1-2], Cayuga[3], Esper[4], are able to provide the more completed and basic processing functions to complex event, They do not consider the data uncertainty in the input event stream and only suite to process to fixed RFID data. Towards the uncertainty RFID data, the system of SASE, Cayuga and Esper cannot detect all possible complex events from input probability data stream and handle all data stream with probability information, so it has a lower efficient event processing capability. Some traditional and common complex event detection methods, such as detection methods based on Petri nets, tree, diagrams and finite automaton and so on, are designed mainly based on deterministic data, therefore, they are not also fit to detect complex events with uncertainty data. With the development of RFID technology, it requires to appear complex event detection system and method with detecting and dealing with uncertainty data.

At present, in order to detect and process RFID data with uncertainty data, Cascadia[5] and Lahar[6] systems have been carried out to solve this problem. But because they are mainly focused on the probabilistic data model based on the original RFID data and related queries based on this model, they do not make more study on uncertainty data of complex event stream and discuss in detail and optimize the probability event in complex event detection .

The Naive method based on the enumeration possible world instance is currently the most widely used method with probabilistic data detection. It mainly combines different values of each data with uncertainty, and lists all of the possible combinations based on detected mode expression, then further match and detect qualifying complex event. However, when there are more events in the input probability event stream, the number of possible combinations is very large, causing exponential number growth of combination data and enormous memory consumption and low detection efficiency in scanning and matching each possible instance in the input RFID data stream, therefore, it is very difficult to meet applications requirement of real-time processing. Especially when the event in input probability event stream is made up of multi-probability events and exists a event model of multi-probability event, the detection efficiency of the Naive method will be much lower.

In this paper, aiming to solve the problems of big combinations number of possible events and high memory consumption and low detection efficiency for Naive method during the detection process of multi-probability RFID event streams, we propose a complex

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event detection methods based on NFA-DAG (Nondeterministic Finite Automaton - Directed Acyclic Graph) for multi-probability RFID event stream in this paper. The contribution of the new method lies that we use uses the union of NFA and DAG to detect multiple-probability RFID event stream, which can solve many problems above existed in Naive method can be solved efficiently. The simulation results show that our proposed scheme in this paper can reduce the combinations number of possible event and lower memory consumption and improve detection efficiency compared with Naive method, without degrading detection quality.

The rest of this paper is organized as follows. In section 2, the related work of complex event detection is introduced. The proposed multiple-probability detect method is presented in section 3. The experimental results and analysis of proposed scheme compared with Naive method are presented in section 4. In section 5, we give some conclusions.

II. RELATED WORK OF COMPLEX EVENT DETECTION

Complex event detection is such activities to find interest or unusual events to the user in the detection process. It mainly diggings out meaningful information from the generated volume data, automatically analyzes the event, real-timely extracts and records interest events to the user, integrates a series of atomic events into a complex event, achieves the complex event detection, and improves the system processing efficiency. The introduction of complex event detection not only can reduce the processing burden of event system, but also can greatly expand the event processing power and flexibility of the system. At present, complex event detection methods can be divided into two categories: complex event detection based on fixed data structure and complex event detection based on probabilistic data structure.

In complex event detection based on fixed data structure aspect, Bai et al. [7] used a method based on graph to detect complex event. Sun et al. [8] used a method based on tree to detect complex event. Mei et al. [9] used finite automaton to detect complex event from active database. Wang et al. [10] used method based on Petri net to detect complex event from active database. In the paper [11], a TPN (Timed Petri-Net) was proposed to detect complex event for RFID stream. Zang et al.[12] used method based on workflow to detect complex event pattern for RFID stream. In the work [13], a query plan based on complex event detection method SASE was proposed. It used the union of NFA (Nondeterministic Finite Automaton) and stack to detect complex events and optimize the problem of large sliding windows and large intermediate result size existed in event detection. But the shortcoming of original SASE method lies that it can't process hierarchical complex event and get acceptable performance when the sliding window is large.

In complex event detection based on probabilistic data structure aspect, recently some works have been carried out to study for them. Segev et al. [14] suggested uncertain complex event grammar rule expression through expanding the definition of ordinary complex events using probability theory and presented a method to calculate the probability of complex events based on Bayesian network and sampling method. Kimelfeld et al.[15] used statistical models and Markov sequences to represent the uncertain RFID data stream and proposed to use the Markov sequence converter to achieve sequence event matching. But this method does not support the operation and maintenance of the probability of conversion process. letcher et al. [16]studied the event query descent matter in Markov flow by pedigreeing chart records and querying uncertain events matching process. And in the end, they proposed a descent-based query linear algorithm to efficiently query uncertain events in the history matching process for larger uncertain events in the RFID event stream. In the paper of [17], a query language was presented for probabilistic complex events detection, which allowed users to express Kleene closure patterns with a new data structure AIG when it was used to detect probabilistic complex events. In the work of [18], a data structure called CIQ(Chain Instance Queues) was suggested to detect complex events with single scanning probabilistic stream and CPI-Tree (Conditional Probability Indexing-Tree) was used to store conditional probabilities of Bayesian network for its high detection performance. Wang et al.[19] proposed a high performance complex event processing method over distributed probabilistic event streams. In this paper, they used probabilistic Nondeterministic Finite Automaton and Active Instance Stacks to process complex event in single probabilistic event stream. Angiulli et al.[20] introduced a novel indexing technique based on UP-index to solve the problem of efficiently answering range queries over uncertain objects in a general metric. In this paper [21], Kawashima et al. proposed an optimized method to process complex events. Their proposed method not only can calculate the probability outputs of compound events, but also can obtain the value of confidence of the complex pattern against uncertain raw input data stream. In this paper, in order to manage the runtime against probabilistic stream, they also extended its evaluation model NFAb automaton to a new type of automaton on the basis of the existing stream processing engine SASE+.

III. PROPOSED SCHEME

A. Detection Principle of NFA-DAG Algorithm

In this paper, in order to solve the problems of big combinations number of possible event and high memory consumption and low detection efficiency existed in Naive method in detecting multi-probability RFID event streams, we present a complex event detection method based on multiple-alternative RFID event stream. The basic idea of our algorithm is that we uses the union of Nondeterministic Finite Automaton (NFA) and Directed Acyclic Graph(DAG) to detect multiple-probability RFID event stream, as a result, the problems above existed in Naive method can be effectively improved. Detection principle of NFA-DAG algorithm can be shown as in figure 1.

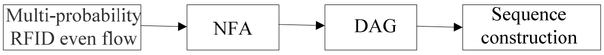

Figure 1. Detection principle of NFA-DAG algorithm

From figure 1, we can see clearly that the detection principle of our NFA-DAG method mainly includes four parts: multiple-alternatives RFID event stream, NFA, DAG and sequence construction. Multiple-alternative RFID event stream mainly offers multiple-alternatives data source for NFA-DAG algorithm. NFA mainly scans inputted multiple-alternatives data stream, DAG mainly processes matched multiple-alternatives data, sequence construction mainly constructs all event sequences and changes event stream into event sequence stream.

B. Realize Process of NFA-DAG Algorithm

In order to realize the detection process of NFA-DAG algorithm, it needs to include some main steps as follows: (1) extract primitive events from multiple-alternatives RFID event stream. (2) detect related events according to specific rules. (3) process related events to form business event with event operators. (4) sent response to the actionable business information.

The detailed realizing steps for our proposed NFA-DAG algorithm can be summed up as some steps as follows:

Step1, build corresponding NFA according to complex event detection expression, create and initialize active set S;

Step 2, input multi-probability RFID event stream;

Step 3, judge whether state transition in NFA to occur according to its transition rules and current active state when it receive possible event in multi-probability RFID event stream. If yes, go to step 4 to execute; otherwise, skip step 5 to perform.

Step 4, judge further whether the transition state in NFA is the initial state. If it is the initial state, establish a new DAG, add a new node composed by the possible event and current active state and a direct side of new node pointing to the initial node for the DAG. Then update the active set S (add new transition state into active set S and delete the old transition state from active set S); otherwise, add a new node composed by possible event and current active state and some direct sides which point to from new node to all nodes related current transition state for the DAG. Then update the active set S (add new transition state into active set S and delete the old transition state from active set S);

Step 5, scan cyclically the next state of active state S and receive the next possible event in the input multi-probability RFID event stream until the end of detection work;

Step 6, search all such nodes whose termination state is received state as a starting point and do the depth-first search to such nodes, if the path are able to reach the initial node above, all nodes and evens in the path can constitute a matching sequence, and the matching sequence is the required complex event. Table 1 is pseudo code of our proposed NFA-DAG algorithm.

TABLE 1

PSEUDO CODE OF OUR PROPOSED NFA-DAG ALGORITH

```
Procedure NFA-DAG_Detection{
  Input: complex event detection expression, multi-probability event stream
  Output: matching complex event  sequence
 (1)initialization
 (2)build NFA ◄— NFA_Creation();
 (3)initialize Active set ◄— Creat_Initialize_Activeset();
 (4)input multi-probability RFID event stream;
 (5)judge state transition in NFA ◄— transition rules and current  active state
 (6)if (state transition in NFA==transition){
 (7)if (Transition state in NFA == the initial state){
 (8)  establish a new DAG,
 (9)  add a new node  and a dirEct side ◄— Add_Node() and Add_Diredside()
 (10) update  active set S;
 (11) }
 (12)else{
 (13)  add a new node  and some direct sides ◄— Add_Node()  and Add_Diredside()
 (14)  update active set S
 (15)  }
 (16) }
 (17)scan cyclically the next state in active state S
 (18)receive the next possible event from multi-probability RFID Event stream
 (19)if ( detection work!= End)
 (20)   start the next detection work ◄— skip step (5);
 (21 else{
 (22) find all end nodes
 (23)  for each end node ◄— Depth_First_Search ();
 (24) if (search path==reach the initial node){
 (25)     get required complex event
 (26)     output required complex event
 (27)  }
 (28)  }
 (29)}
```

C. Case Study of NFA-DAG Algorithm

Take detect complex event expression SEQ (a, b [], c) in multi-probability event stream shown in table 2 for example to illustrate the realization process for our proposed method above, where b [] means that there are one or more b type of event.

TABLE2

MULTI-PROBABILITY RFID EVENT INPUT STREAM

Timestamp	1	2	3	4	5
Event(id)	A(11) /b(11)	B(21) /c(21)	A(31) /c(31)	A(41) /b(41)	b(51) /c(51)

Step1, build the corresponding NFA shown in figure 2 according to the corresponding complex event detection expression of SEQ (a,b[],c), create active set S and initialize S as 0;

Step 2, input multi-probability RFID event stream;

Step 3, judge whether state transition in NFA has occur based on its transition rules and current activity status when it receive a possible event from multi-probability RFID event stream above, such as event a(11) or b(11), a(21) or c(21) and so on, The detailed detection process of every possible event in each timestamp is described as follows:

Step 4, in timestamp 1, when event a(11) or b(11) arrives, according to the transfer rule of NFA and current active states(0), a(11) can make NFA generate state transition, create a new DAG, add a new node (a (11), 1) and a direct side from node (a (11), 1) pointing to the node O, while event b(11) cannot make NFA generate state transition, at last, update status transition(0,1) in active set S.

Step 5, in timestamp 2, when the event b(21) or c(21) arrives, on the basis of the NFA transition rules, in the active state 0, event b(21) and c(21) cannot make NFA generate state transfer; in the active state 1, b(21) could make NFA generate state transition from state 1 to state 2 and add a new node (b(21), 2) and a direct side from node (b(21), 2) pointing to node (a(11), l), while event c(21) does not make NFA generate state transition; at last, update status (0, l, 2) in active set S;

Step 6, in timestamp 3, when the event a(31) or c(31) arrives , based on NFA transition rules , in the active state 0, a(31) can change NFA state from 0 to 1, create a new DAG, add a new node (a(3l), 1) and a direct side from node (a(3l), 1) pointing to O node; in the active state 1, both a(31) or c(31) cannot change NFA state; in the active state 2, only event c(31) make NFA state change from 2 to 3 and add a new node (C(31), 3) and a direct side from node (C(31), 3) pointing to node (b(21), 2); at last, update activity status (0, l, 2) in active set S;

Step 7, in timestamp 4, when the event a(41) or b(41) arrives, according to the NFA transition rules, in the active 0, events a(41) transfers NFA status from 0 to 1, create a new DAG, add a new node (a(4l), 1) and a direct side of node (a(4l), 1) pointing to O node; in the active state 1, b(41) transfers the NFA state from 1 to 2, add a new node (b(41), 2) and a direct edge of node (b(41), 2) pointing to node (a(31), 1). in the active state 2, both event a(41) or b(41) cannot change NFA state; at last, update activity status (0, l, 2) into active set S;

Step 8, in timestamp 5, when the event b(5l) or c(51) arrives, according to NFA transition rules, in the active state 0, both event b(5l) or c(51) cannot make NFA state change in the active state 1; in the active state 2,event b(51) can make NFA state change from state 1 to state 2; b(51) could also make NFA state shift from state 2 to state 2, adds a new node (b (51), 2) and two direct sides from node (b(51), 2) pointing to node (a(41), 1) and from node (b(51), 2) pointing to node (a (41), l); in the active state 2, c(51) also make NFA state change from 2 to 3 and add a new node (c(51), 3) and a direct side from node (c(51), 3) pointing to node (b (41), 2); at last, update activity status (0, l, 2) into active set S;

Step 9, after finishing building DAG, search all the nodes whose termination state is received state as a starting point, such as node(c(31), 3) and node c((51), 3) in figure 3, then do the depth-first search to these nodes to search all paths to reach the initial O node ,such as do depth-first search from starting node (c(31), 3) and (c(51), 3). If the paths above are able to reach the initial node O, all node and evens in the path can constitute a matching sequence, such as three matching sequence: a(11) b(21) c(31) and a(31) b(41) c(51) in figure 3, they are the required matching sequence of complex event. To here, all event sequence scan has completed. The final detection result is shown as in figure 3.

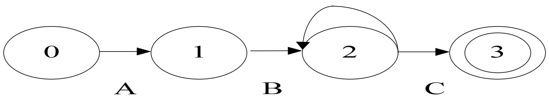

Figure 2. NFA for complex event expression SEQ (a, b [], c)

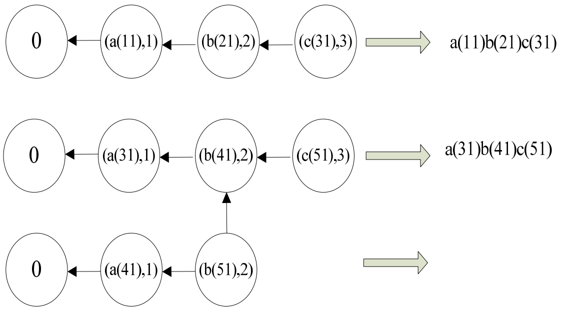

Figure 3. Detect result in multi-probability RFID event stream

From figure 3, we can observe that, with the union help of NFA and DAG, our proposed method in this paper could realize the complex event detection in multi-probability RFID event stream, which can greatly reduce the combinations number of possible events, lower memory consumption and improve detection efficiency for Naive method in detecting multi-probability RFID event streams. Our proposed complex event detection method base on NFA-DAG is a more high-efficient complex event detection method, which not only improves complex event detection methods based on automation, but also extends the existing complex event detection technology and makes it easier to complete the complex event detection with uncertain data.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

In this paper, a complex event detection method based on multiple-alternatives RFID event stream has been presented. In order to verify the effectiveness of our proposed method above, we take some experiments. Our designed experiments mainly include four parts: experimental environment, test the combination number of possible event with different possible events number, test memory consumption with different possible events number and test event throughput with different possible events number.

A. Experimental Environment

The simulation environment was conducted on Microsoft Windows 7 operating systems, AMD A6-3420M 4 core CPU Processor, 2G memory, 500G Hard disk. In our experiment, we use the tool Visual C++ 6.0 to realize data generator and make use of the data generator to generate kinds of required multi-probability RFID event stream by controlling the generated event types, the number of possible options event, event probability distribution parameters and so on. We add some necessary processing functions for uncertain event based on SASE system and modify the original core method of sequence scan and sequence construction in SASE to evaluate our supposed method. Table.3 is some main experimental parameters set in our experiment for this paper.

TABLE 3
MAIN EXPERIMENTAL PARAMETERS IN OUR EXPERIMENT

Test indicator	Test parameter
① combination number of possible event ② memory utilization of detecting event ③ throughput	① sliding window size: 5 ② generated event types : abcde ③ possible option number for each event: 1-10 ④ detection mode SEQ (a, b [] c)

B. Test the Combination Number of Possible Event with Different Possible Events Number

In this subsection, we evaluate the combination number of possible event with different possible events option number for our supposed method. Figure 4 is the experimental comparison results.

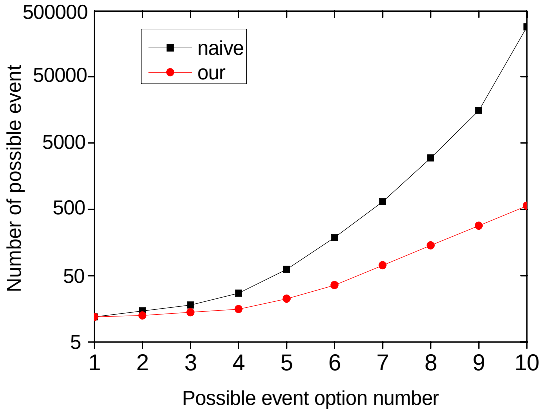

Figure 4. Combination number comparison of possible event with different possible events option number

From figure.4, we can see clearly that, with the number growing of different possible event option, our algorithm shows smaller combination number of possible events compared with the Naive method during the detection process of the same multi-probability RFID event stream. The reason for it is that we use NFA and DAG to detect multiple-alternatives complex RFID event stream, which can reduce many combination number of unnecessary possible events due to the union use of NFA and DAG. In figure 4, we also observe that our algorithm is equivalent to the Naive method in combination number of possible event when the number of possible event options is less than 3. But with the number increasing of the possible events option, the combination number of possible event in Naive method evidently increase, while our algorithm present to add in a relatively flat way.

C. Test Memory Consumption with Different Possible Events Number

In this subsection, we mainly take an experiment to test the memory consumption during the detection process of multi-probability RFID event stream with different possible events option number for our method compared with naive method. The experimental comparison result is shown in figure 5 as follows.

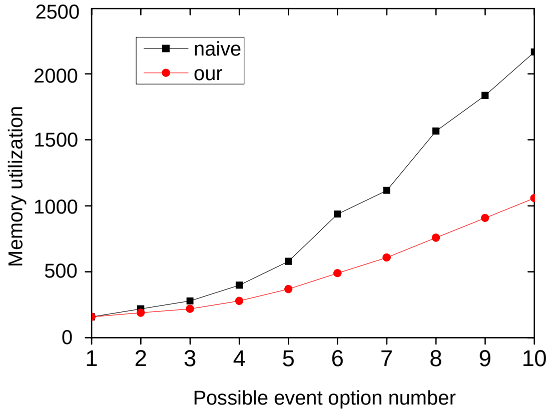

Figure 5. Memory utilization comparisons with different possible events option number

From figure 5, we can clearly observe that, compared with Naive algorithm, our proposed algorithm has a significant improvement in saving event memory utilization during the detection process of multiple-alternatives complex event detection. The main reason for it is that we use NFA and DAG to reduce the memory consumption during the detection process of multiple-alternatives RFID event stream, which can save lots of detection memory utilizations of events that do not meet detection requirement. In figure 5, we also see that, when the number of event possible options events is less than 3, our algorithm is equivalent to the Naive method in event memory utilization. However, when the number of possible events option is more than 3, the memory consumption of Naive method in detecting multiple-alternatives complex event increases sharply, while our algorithm can present more gentle change.

D. Test Event Throughput with Different Possible Events Number

In this subsection, we detect complex events throughput for our proposed method compared with naive method with different number of possible events option. The experimental result is shown in figure 6 as follows.

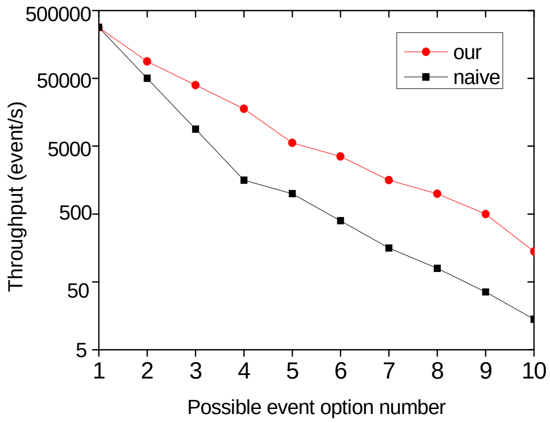

Figure 6. Event throughput comparisons with different possible event option number

From figure 6, we can see clearly that, with the different possible event option, our algorithm shows better event throughput capabilities compared with the Naive algorithm during the detection process of multi-probability RFID event stream. The reason for it lies that we use NFA and DAG to detect multiple-alternatives complex RFID event stream, which can accelerate many event detection speed and save much memory consumption, therefore improving event detection throughput. In figure 6, we also observe that, when the number of event possible options events is relatively smaller, our algorithm is equivalent to the Naïve method detection in event detection capabilities. But with the number increasing of the event possible option, the throughput capabilities of Naive method sharply decrease, while our algorithm shows a downward relatively flat.

V. CONCLUSION

In this paper, a new complex event detection method based on NFA-DAG is presented to improve the detection performance for multiple-alternatives RFID Event Stream. In our scheme, we use the union of NFA and DAG to detect multiple-probability RFID event stream, which can effectively solve some problems existed in Naive method. The simulation results show that our proposed scheme has a great improvement in reducing a lot of combinations number of possible event, lowering memory consumption and improving detection efficiency during the detection process of multi-probability RFID event streams compared with Naive method.

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REFERENCES

[1]. Gyllstrom D, Wu E, Chae H J. "SASE: ComPlex Event Proeessing over Streams," Rro of CIDR, pp.407-411, Dec.2007

[2]. A grawal J, Diao Y, Gyllstrom D, etal. "Efficient pattern matching over event streams," Proeeedings of the 2008 ACM SIGMOD international conference on Management of data. pp. 147-160, June. 2008

[3]. Brerma L, Demers A, Gehrke J, "Cayuga: a high-Performance event Processing engine," Proeeedings of the 2007 ACM SIGMOD international conference on Management of data. pp.1100-1102, June, 2007

[4]. Esper Team , Wayne N J, "Esper Reference Documenta-tion," http://espen codehaus.Org/espefio-1.7.0/doc/refefence/,August,2009

[5]. E. Welbourne, N. Khoussainova. "Cascadia: a system for specifying, detecting, and managing RFID events," pp.281–294, MobiSys, June.2008.

[6]. R-e C, Letehner J, Balazinska M. "Event Querieson Correlated Probabilistie Streams," Proc of the SIGMOD Conf. pp.715-72, June. 2008

[7]. L. Bai, S. Lao, A. F. Smeaton, N. E. O'Connor, D. A. Sadlier, and D. Sinclair. "Semantic analysis of field sports video using apetrinet of audio-visual concepts," Comput. vol 52,no7.pp. 808–823.2009

[8]. Xiangwei Sun, Rong Chen, Zhenjun Du. "Composite Event Detection Based on Automata," 2009 IEEE International Conference on Intelligent Human-Machine Systems and Cybernetics, pp.160-163, Aug. 2009.

[9]. Mei Y, Madden S. "ZStream: A cost-based query processor for adaptively detecting composite events," Proceedings of the SIGMOD2009. pp193-206, July. 2009

[10]. F. Wang, S. Liu, P. Liu, "Bridging physical and virtual worlds: complex event processing for RFID data streams," LNCS 3896: the 10th International Conference on EDBT, pp.588- 607. March. 2006

[11]. X. Jin, X. Lee, N. Kong, et al."Efficient Complex Event Processing over RFID Data Stream," ACIS-ICIS, pp.75-81. 2008,

[12]. C. Zang, Y. Fan. "Complex event processing in enterprise information systems based on RFID. Enterprise Information Systems," vol.1,no 1, pp.3-23. 2007

[13]. Segev W, Avigdor G, Opher E. "Handling uncertain rules in composite event systems," 2005 LAIRS Conferenee. pp.860-861, May.2005 ,

[14]. Wu E, Diao Y, Rzvi S. "High-performance complex event processing over streams," Proceedings of the 2006 ACM SIGMOD international conference on management of data. pp.407-418, June, 2006,

[15]. Kimelfeld B, Re C. "Transducing markov sequences," Proceedings of the twenty-ninth ACM SIGMOD-SIGACT-SIGART symposium on Principles of database systems of data. pp.15-26, June.2010,

[16]. Letchner J, Balazinsks M, "Lineage for Markovian stream event queries," Proceedings of the 10th ACM International Workshop on Data Engineering for Wireless and Mobile Acess. pp. 26-33, June. 2011

[17]. Z. Shen, H. Kawashima, and H. Kitagawa. "Probabilistic event stream processing with lineage," In Proc of the Data Engineering Workshop, vol 2, no 4, pp.355-74, 2008.

[18]. C. Xu, S. Lin, W. Lei, et al. "Complex Event Detection in Probabilistic Stream," Proceedings of the 12th International Asia-Pacific Web Conference (APWeb 2010). pp. 361-363, April.2010.

[19]. Yongheng Wang, Xiaoming Zhang. "Complex Event Processing over Distributed Probabilistic Event Streams," 2012 9th International Conference on Fuzzy Systems and Knowledge Discovery,pp.1489-1493,May. 2012

[20]. Fabrizio Angiulli, Fabio Fassetti, "Indexing Uncertain Data in General Metric Spaces," IEEE transactions on knowledge and data engineering, VOL.24,NO.9, pp.1640-1657,2012

[21]. H. Kawashima, H. Kitagawa and X. Li. "Complex Event Processing over Uncertain Data Streams," Proceedings of the fifth international conference on P2P, parallel, grid, cloud and internet computing.pp.521-526, Nov,2010.

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