

Research on the Conceptualization model for Traceability System of Meat Food Quality Safety

ZHANG XIAOSHUAN¹ ZHANG JIAN² ZHANG HU³ MU WEISONG^{1*}

¹ College of information and electronic engineering
China Agricultural University

No.17 Qinghua Donglu, Haidian District, Beijing100083
P. R. CHINA

² College of economics and management
Beijing Information S&T University,
Beijing, 100192

P. R. CHINA

³ College of Engineering

China Agricultural University

No.17 Qinghua Donglu, Haidian District, Beijing100083
P. R. CHINA

*Corresponding author, Email: zhxshuan@cau.edu.cn

Abstract: The quality safety traceability of meat food has played important role in governmental law, food industry management strategies, and consumers. Many institution and software companies have developed a lot of traceability system. There is a growing perception to implementation of reusability, multi resource data fusion and information sharing of the different system. The conceptual model is the key basic for the system reusability. The paper proposes an conceptual model of traceability system via integrating Petri nets, FMECA, with fuzzy probability, theory of evidence. The traceable resource unit(TRU) is classified and the information flow is optimized. The result shows that the model can improve the reusability and sharing of traceability system, consequently improve the efficiency and decision-making quality for fast position and forward early warning in meat food quality safety traceability.

Keywords: meat food, quality safety, traceability, Petri Network, FMECA, information fusion

1 Introduction

In recent years, food safety in general and meat safety in particular has become a major factor influencing meat purchasing and consumption behavior beyond China and across world, especially the meat food, because the possession and consumption level of meat products is one kind of index, which evaluate the degree of civilization of a country and life quality of the people. China is one of

largest country with meat production and consumption. Meat food industry is playing a important role to improve the farmers' income, develop the rural economics, protect consumers health and the expand the foreign trade export growth. China produces around 80510 thousand tonnes of meat food at year 2006, of which about 3 percent is exported due quality safety. During the last decade, the Chinese meat food industry has become increasingly concentrated with a substantial reduction in the number, and increase in the

size. On the other side, consumption of meat food has been steadily rising in recent years. After year 1990 meat food consumption has been boosted by growing consumer concerns related to health, convenience and variety, specially the pig meat reached 39.6 kilogram, mostly doubled that year 1990(20 kilogram).

The restoration of national and international consumer confidence is a major challenge for the Chinese meat industry and considerable efforts have been made to improve the regulation of production, process and distribution systems in the meat industry. Traceability system, as a key instrument in this respect, has become a critical element in global agri-food business. In January 2002 in EC 178/2002, EU laid down the general principles and requirements of food law, established the European Food Safety Agency (EFSA) and sets out new food safety standards. By the 1st January, 2005, all European food and feed business operators, including primary producers, must have systems and procedures in place to identify from whom these businesses have been supplied and to whom their products have been supplied. Similar requirements for traceability system are present in the USA, and Japan. Repeated violation of the regulation governing such substances has lead to a ban being imposed on those products originating from that country. Along with the requirement, The Chinese government, inspired by China being the host country for 2008 Olympic Games and one of the largest agricultural and food export country, has also implemented and issued corresponding laws and regulations to guarantee quality safety of agricultural products.

So the shifting patterns in consumer demand for sustainable agricultural practices (including environmental and animal welfare concerns) and ever-increasing demand for consistent supply of a range of top quality and safe products assure a future for traceability as an important element of the overall quality assurance system [1]. Consequently, the traceability of agricultural products quality is becoming both food enterprise strategic management and the focus that customer pays attention to.

Many literatures show there are lots of traceability

system had been developed by different organization [2-9]. China also launched the traceability project from 2004 year, mostly focus in bulk live and fresh agricultural product, like vegetable, fishery and meat [10-12]. Radio Frequency Identification (RFID) is used in traceability system [13-15]. But there usually develop a common service platform as a universal information system to be suitable to any business.

Generally speaking, this paper proposes the conceptual model case study by meat food via integrating Petri net with artificial intelligent technology.

2 Material and methods

2.1 survey for the traceability information flow

Traceability management implies the collection, storage, processing and delivery of huge amounts of information all along the food chain, which should be permanently available to all the agents involved in the process, from farmers to final consumers.

A questionnaire is designed for survey the traceability information flow. It suppose to provide structured means to obtain general information about the chain actors, and important details about the technical requirements required for the development criteria of the solutions and system developments. Also the questionnaire gathers together information about many of the parameters relating the particular chain actor current use of technologies, as well as their possible future expectations and technological needs. The questionnaire gives flexibility to users to select how much of the relevant information is collected via the question or by filling in the relevant event-actor tables as adapted to different chains. However, the chain mapping needs to give as a complete overview as possible of the product flow/transport along the chain, recording the events, product specific and environmental parameters.

2.2 Petri Net application

In meat supply chain, the interaction of between internal factors, the interaction of system, environment and operation changes the quality safety path and results. It is useful to evaluate the supply chain safety, eliminate and control the risk and prevent the risk event, improve the quality safety via understanding the dynamic change. Therefore, food safety in the modeling analysis, it is necessary to consider its function, structure, such as static characteristics, but also consider its implementation, interactive, such as dynamic behavior.

Although static safety analysis model can illustrate the behavior process of the system with a graphical description, it is still quite abstract, is neither intuitive nor easy to use. For example, the minimum cut sets and minimum path set are the analysis results of the system reliability and security analysis in the risk tree model. But the minimum cut sets and minimum path set only are understood by who have more in-depth knowledge of systems analysis personnel. In addition, if the system designers are not familiar with the reliability, security analysis, he or she can not build accurately model of system risk. It seriously hampers the communication between the system designer and reliability, security analysts.

Petri net model is able to meet this requirement. According the Wiki, a Petri net consists of places, transitions, and directed arcs. Arcs run between places and transitions, never between places or between transitions. The places from which an arc runs to a transition are called the input places of the transition; the places to which arcs run from a transition are called the output places of the transition. Places may contain any non-negative number of tokens. A distribution of tokens over the places of a net is called a marking. A transition of a Petri net may fire whenever there is a token at the end of all input arcs; when it fires, it consumes

these tokens, and places tokens at the end of all output arcs. A firing is atomic, i.e., a single non-interruptible step. Execution of Petri nets is nondeterministic: when multiple transitions are enabled at the same time, any one of them may fire. If a transition is enabled, it may fire, but it doesn't have to. Since firing is nondeterministic, and multiple tokens may be present anywhere in the net (even in the same place), Petri nets are well suited for modeling the concurrent behavior of distributed systems.

Then Petri net can integrate data flow, control flow and state transition, easily describe in the distribution system, concurrent, synchronous, asynchronous, and other characteristics of the conflict. Moreover, the conflict is just another of the system by the staff to intervene and control the local demonstrated the interaction and the system. At the same time, the format of internal and external event can be unified using tokens change in the web express system re-distribution of resources and as interactive media. In addition, Petri nets can expand in the transfer of time, such as time Petri nets (Timed Petri Nets-TPN), random Petri nets (Stochastic Petri Nets-SPN), generalized stochastic Petri net (Generalized Stochastic Petri Nets-GSPN), they express more clearly the performance of the system of the time factor, so a more realistic description of the dynamic system characteristics of the random.

Petri net model and its expansion have an important advantage, which is its graphics demonstrates the capacity of a richer, with intuitive, easy-to-understand, easy to learn and use characteristics than the other way. These characteristics make the system design of Petri net between staff and analysis of bridges, the system will help to establish more accurate, true model than the traditional model.

2.3 FMECA and integrated with Petri Net

As a powerful graphical tool for dynamic modeling, Petri net describes not only the static structure, but also

simulation of dynamic systems ensure the food safety of meat retrospective analysis more completely and thoroughly. Petri net model can solve the hazard risk at the same time, gain the Petri reachability nets. This process needs much work. During the modeling, some parameters require rich data and in-depth understanding. Many methods been adopted in reliability, safety analysis, like Failure Mode, Effects, and Criticality Analysis (FMECA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA), are useful to improve the system safety.

According the Wiki, FMECA is an extension of Failure Mode and Effects Analysis (FMEA). In addition to the basic FMEA, it includes a criticality analysis, which is used to chart the probability of failure modes against the severity of their consequences. The result highlights failure modes with relatively high probability and severity of consequences, allowing remedial effort to be directed where it will produce the greatest value. The typical goal, when FMECA is performed as part of a design project, is to eliminate failure modes with high severity and probability, and to reduce as much as possible those with high severity and/or probability. If the Criticality Analysis is performed iteratively during the design process, the charted failure modes should be seen to migrate to the left and bottom (typically) of the chart.

These traditional methods can describe the static relationship between the logic variables, but they cannot describe the characteristics of system dynamic behavior and deal with explicit time, the process variable or man-made factors (these factors will affect the dynamic response of the system), involve to system changes over time in the system state, as well as parts of the evolution of factors such as risk caused by the different timing of the impact of system security differences. For example, Hazards tree models need analyze the reasons caused expected state (including environmental and human factors), solve the occurrence probability of top event from the system structure and function. But when the top events occur can be not obtained. Moreover, the dynamic characteristics of the system are important information,

the difference of the risk consequence maybe result the different influences for the system security.

Given that both Petri net-based analysis of security system technology and the traditional safety analysis techniques have their benefit and limitations, respectively, it is the trend to integrate in the system safety analysis process, they can combine into comprehensive applications: Petri net model can provide a detailed description of the system, including static and dynamic characteristics of information. Those information are the basis of the system security analysis, but also provide the help for the implementation of the FMECA and the establishment of event tree and risk tree; And FMECA, ETA and FTA methods provide the systematic, standardized and effective tool for security analysis, and provide the aid for structure and evaluate the Petri nets modeling given that FMECA, ETA and FTA method are one kind of mature, uniform, standardized process that can effectively search for system security flaws.

There are two directions integrating Petri net with FME(C) A: one is positive PF method. Positive PF can apply the FME(C)A on Petri net models, render the Petri Net model as the analysis objective, the factor of Petri net models as the component of FME(C)A, i.e. the risk part of the FME(C)A results is the elements of Petri net models, rather than the physical structure of the real system. The other is the reverse PF. It firstly survey the real FME(C)A, analyze the causes of hazards model and impact of hazards for system security, compare which factors are the important for the product safety, further describe significantly via the transfer in FME(C)A model. The hazard rate of the components is the fire probability of the transfer in Petri net, i.e. FMECA provides some input for the quantitative analysis of the Petri net model.

2.4 Evidence theory and information fusion

The advantages of the model integrated Petri Net and FMECA is the model can analyze and judge the process of meat production, but it is subject to the experience of the experts, the users subjective, and these experiences are the decision evidence for the

traceable trade unit risk during the quality safety traceability system.

Conventional decision-making theory is based on probability theory and mathematical statistics, thinks the probability is fully determined by the frequency of the incident (as evidence), is purely objective. Then the theory emphasis one-sided on the role of evidence ignores the decision role of people. The subjective Bayesian probability theory think probability is a measure for preference or subjective of people, is purely subjective, that is, the theory emphasis one-sided on the role of people's decision, while ignoring the role of objective evidence.

Evidence theory, invented by Dempster and later developed by his student Shafer, is an extension of classical Probability Theory. However, its importance was not immediately recognized until researchers first began to investigate applications of the theory to expert systems [16]. The theory thinks for the understanding of probability inference, both evidence objectivity and subjective estimates should be emphasized. The probability is the reliability which proposition is true people structure based on the evidence. Therefore, the evidence theory can make the correct decision via inducting and estimating every component probability based on a variety of information systems. Evidence Theory is a theory on the judgment, and new kind of method to explain the probability, which is different from the traditional Bayesian probability theory and used to describe the uncertain information, and information fusion.

FMECA [17] methods can analyze and evaluate the risk of potential harm (severity, frequency and detection of degree) for specific operating procedures of meat food production chain, then arrive at quantitative indicators and identify critical control points. However, in the process of assessment, the time constraints and the lack of data and uncertainties and other related issues will lead to uncertainty and fuzzy decision-making, and thus the risk analysis of the last great difficulties. So the evidence theory will adopt to information infusion and improve FMECA conclusions of the meat production process.

Evidence theory assumes the definition of (1) a

frame of discernment Ω consisting of the exhaustive and exclusive hypothesis and (2) the reference set (set of all subsets) 2^Ω of all the disjunctions of the elements of Ω [18]. Evidence theory proposes the idea of using a number in the interval [0, 1] to indicate the degree of evidence supporting a proposition.

3 Results and discussion

3.1 the traceability information flow model and interference

The basic characteristics of traceability systems are: identification of units/batches of all ingredients and products; information on when and where they are moved or transformed; and a system linking these data. In a food production system, for each lot processed, n lots from an equal number of production cycles can be used. Each food chain, which may extend from nodes producing the raw materials to distribution, may also be interwoven with other chains, sharing one or more intermediate processing nodes (see Fig. 1).

The first task of traceability system is to seek the risk model which result the quality unsafe of meat food. Fig.2 shows the interference flow of quality traceability information. Petri network can simply all kinds of risk factors into the place and transmission. Consequently, more simply the quality transmission relationship, more discovered quality risk transmission model. The meat quality safety traceability network is expressed equation 1 based on Petri net definition.

$$\sum = (P, T, F, W, TL, M_0) \quad (1)$$

Where : $P = \{p_1, p_2, \dots, p_n\}$ is place's limited sets, means the quality vector of every process ; $T = \{t_1, t_2, \dots, t_m\}$ is limited vector sets of quality transmission, means quality safety risk arise and change ; F is the sets of all kind of directional arc, W is weigh function ; TL is transmission label sets,

$M_0 = \{M_0(p_1), M_0(p_2), \dots, M_0(p_n)\}$ is initial

status of quality, mean the risk factor distribution function.

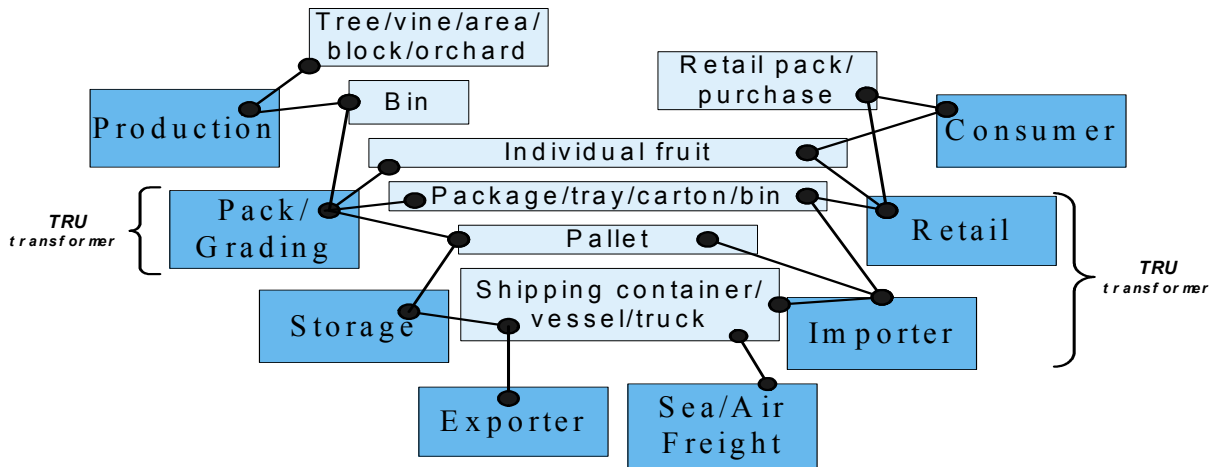


Fig. 1 the meat food quality traceability information, adopted from Moe, 1998

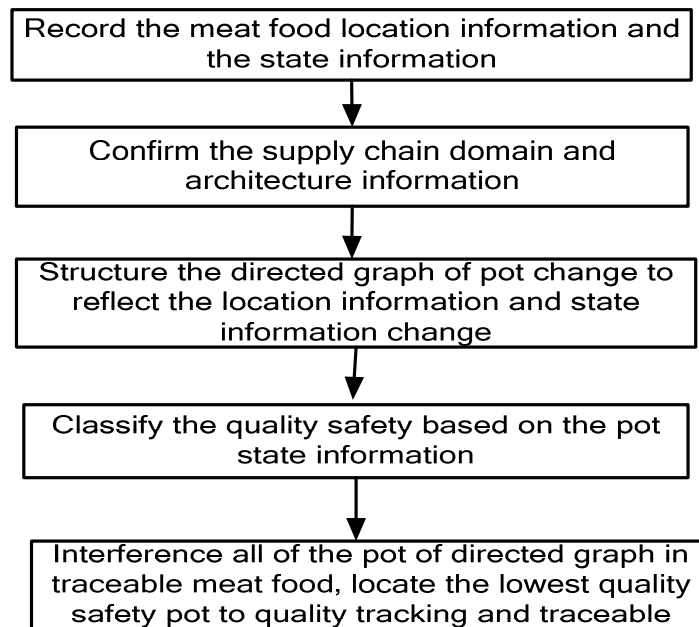


Fig. 2 the interference flow of quality traceability information

3.2 the traceable unit classification and transmission process

The concept of traceable units is a key concept in chain traceability in general. It is unique label information in the supply chain and can be exchanged between two parties in the supply chain. The traceable unit is classified based on the meat produce methods, management models, cost and quality parameter into single unit-based, batch-based and time series-based.

According to <http://www.tracefood.org>, it classifies into a Trade Unit (TU) and a production batch:

- A Trade Unit (TU) is defined as ‘any item upon which there is a need to retrieve predefined information and that may be priced, or ordered, or invoiced at any point in any supply chain’.
- A production batch is also an important traceable unit which has to be referred to when dealing with internal traceability. A production

batch is the traceable unit that raw materials and ingredients go into before they are transformed into products placed in new Trade Units and Logistic Units.

A product may be tracked to different levels of detail, or granularity, through the supply chain. The typical Traceable Resource Units (TRU) are shown in Figure 1. The TRUs are generally defined as any unit that is unique and cannot have the same attributes as another unit [19]. Any one TRU comprises a number of smaller TRUs; for example, a shipping container is filled with pallets, which in turn have a number of cartons or packs stacked on each.

The size of the batches at the individual steps in the supply chain is critical; large batch sizes may be cause

for concern due to the value they represent. It would be beneficial for each step in a supply chain to determine an appropriate batch size based on e.g. the cost of having to destruct large batches during a possible recall, the cost of implementing traceability for smaller batches, and the expected frequency of critical faults [20]. So the traceable unit is beginning and end point of traceability system development and modeling. Its classification influences not only the conceptual framework modeling, but also the traceability problem resolving efficiency and reasoning accuracy. Fig.3 shows the method to optimize traceability of this particular industrial case [21].

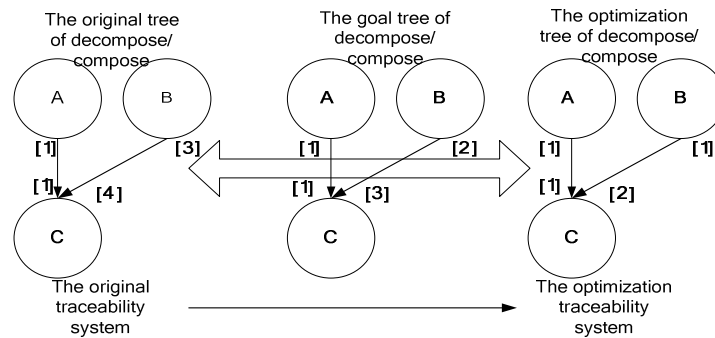


Fig.3 the traceability system optimization

3.3 Quality transmission function of the meat food process

The process of meat food production and processing contains many processing steps. the relationship between its components, includes the relationship between serial and parallel relations(see Fig. 4).

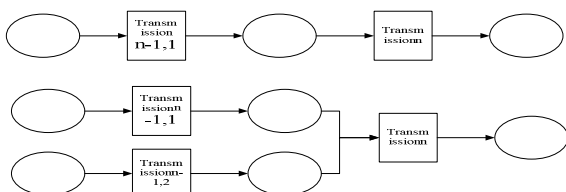


Fig. 4 the quality transmission graph

The quality transfer function is the basis of quality

traceability. Fig.4 shows that the meat food process chain can be combination of single process. Then the information flow can be captured how traceable unit transfers and changes during the food processing. Based on the quality index vector, the state function and transfer matrix can be calculated. Then the transfer function can be confirmed.

$$\begin{aligned}
 P_{n-1} &= \{p_{n-1,1}, p_{n-1,2}, p_{n-1,3}, \dots, p_{n-1,k}\} \\
 P_n &= \{p_{n,1}, p_{n,2}, p_{n,3}, \dots, p_{n,m}\} \\
 T_n &= \{t_{n,1}, t_{n,2}, t_{n,3}, \dots, t_{n,i}\}
 \end{aligned}
 \tag{2}$$

3.4 meat food risk fuzzy prior probability based on FMECA

FMECA consists of two parts, namely, FMEA (Failure Mode and Effects Analysis) and CA (Criticality Analysis). FMECA is a kind of method of bottom-up analysis, records the all possible risk modes during product design and production according to the set rules, analyzes how each model influences the system state (including the overall good, mission success, system

security, etc.) and determines the degree of risk at a single point, then ranks the probability of serious occurrence according to their degree of impact, seeks the potential weak link of the system at last , proposes the improved prevention measures to eliminate or reduce the possibility of accidents occurred to ensure system reliability.

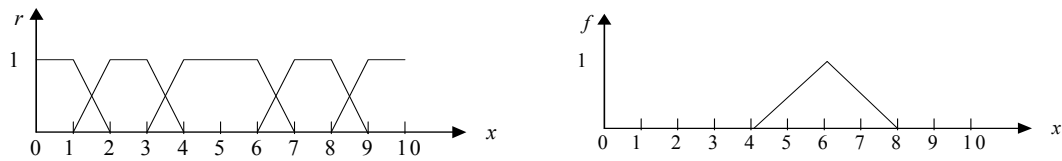


Fig. 5 the quality transmission graph and membership function

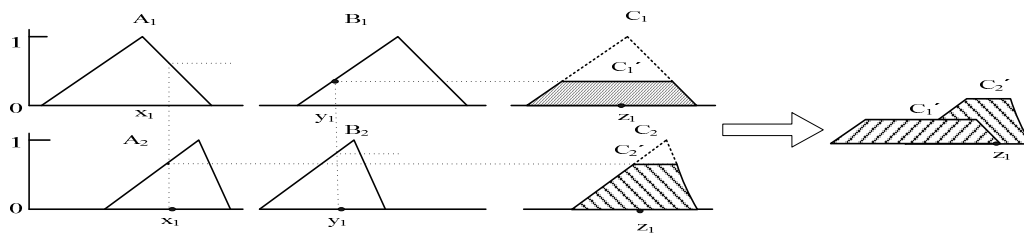


Fig6 the reasoning process of quality safety lot

For the meat supply chain process, the critical control point can be identified via evaluating potential risk (severity, frequency and detection of degree) via filling the "Hazard Analysis and Risk Assessment Form". Figure 5 shows the quantitative calculation process.

The causal and results of meat food risk can be identified based on FMECA and described via the transfer network based on Petri net. Where the risk rate is the transfer fire probability in Petri net. Fig.5 shows the chain probability reasoning process:

The distribution information of every pot can be calculated by the following equation:

$$P(V_q | E) = \frac{P(V_q, E)}{P(E)} \quad (3)$$

$$P(V_q, E) = \sum_{X_R \setminus \{V_q, E\}} \left(\prod_{V_i \in X_R} P(V_i | \Pi_{V_i}) \right) \quad (4)$$

3.5 the traceable and tacking algorithm of meat food traceability

The fuzzy probability model is achieved via introducing fuzzy priori probability into equation 1,

$$WFPN = \{P, T, D, I, O, \beta, \alpha, \lambda, \mu, W\} \quad (5)$$

Where : $P = \{p_1, p_2, \dots, p_m\}$ is all of place sets,

$T = \{t_1, t_2, \dots, t_n\}$ is the limited sets of transfer,

$D = \{D_1, D_2, \dots, D_n\}$ is sets of limited proposition;

$I : P \rightarrow T$, is input function, maps from position sets

to transfer sets ; $O : T \rightarrow P$, is output function, map

from transfer to position sets ; $\beta : P \rightarrow D$ is map

from place to proposition ; $\alpha \in [0,1]$ is the confidence of proposition opposite with place ; $\lambda \in [0,1]$ is the threshold of transfer ; $\mu \in [0,1]$ is Credibility of rule opposite with transfer ; W is the weight parameter from P to T. Plus All of the input arc of Every one transfer equals 1.

3.6 the traceability fusion algorithm integrated D-S evidence theory and FMECA

From the information system perspective, the traceability include two parts: forward and backward traceability.

1) Forward traceability model. The interference is the method which determines the quality of the hazards impact based on known risk omens. The basic principle is from the known conditions, using positively rules, i.e. match a prerequisite condition of the rules with the known fact. If the match is successful, activation of the rules will be added to the known conclusions of the conditions. Then the reasoning continues until no rules match so far.

Input: the initial place vector α^0 , input matrix Δ , output matrix Γ , transmission threshold function λ ;

Output : the end place vector α ;

Step 1 : confirm the initial place vector α^0 :

$$\alpha^0 = [\alpha(p_1), \alpha(p_2), \dots, \alpha(p_j), \dots, \alpha(p_n)]^T, \\ j = 1, 2, \dots, n \quad (6)$$

Step 2 : calculate the transmission vector :

$$E = \Delta \otimes \alpha^0 \quad (7)$$

Step 3 : calculate the transmission reliability vector :

$$\mu = [\mu(t_1), \mu(t_2), \dots, \mu(t_i), \dots, \mu(t_m)]^T, \\ i = 1, 2, \dots, m \quad (8)$$

Step 4 :compare the reliability vector with threshold,

calculate the output matrix :

$$G = \Gamma \otimes (\mu \ominus \lambda) \quad (9)$$

Step 5 : calculate the reliability vector of all of proposition :

$$\alpha^1 = \alpha^0 \oplus G \quad (10)$$

Step 6 :when the transmission reliability vector don't change, i.e. when $\alpha^{k+1} = \alpha^k$, the reasoning ends.

2) Backward traceability model. The interference is the method which seeks the evidence to support reason based on the end products quality. The control strategy assumes the goal exists, then seeks the conclusion relevant with condition from the known conditions in the Knowledge based, verify that the rules are a prerequisite for the establishment of a prerequisite if the information can be matched with known or human-computer interaction are met, then the assumption that the establishment of, or the premise of the rule as a sub-target to repeat the process until all the sub-targets been demonstrated so far. The core of backward traceability is to propose assumptions firstly, and then seek evidence to support this assumption.

4 conclusion

There is a growing perception to implementation of reusability, multi resource data fusion and information sharing of the different system. The conceptual model is the key basic for the system reusability. The paper proposes an conceptual model of traceability system via integrating Petri nets, FMECA, with fuzzy

probability, theory of evidence. The result shows that the model can improve the reusability and sharing of traceability system, consequently improve the efficiency and decision-making quality for fast position and forward early warning in meat food quality safety traceability.

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