Agricultural Supply Chain Traceability System Based on Multi-Agent System

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Abstract In order to overcome defects in existing ASCTS (Agricultural Supply Chain Traceability System, a new traceability system based on Multi-Agent System (MAS) is put forward. By qualitative method, I analyze problems of application of Agent technology in tracing quality of agricultural products. Physical model is built for this system and structure of traceability system is determined. Finally, algorithm is presented for major entities. From analysis of algorithm, it is proved that this system has some reference value in improving breadth and depth of product traceability.
Key words Multi-Agent System, Agricultural product supply chain, ASCTS, Agricultural product security, China

The Agricultural Supply Chain Traceability System (ASCTS) refers to the system in which relevant information is recorded in the production, processing and circulation of agricultural products, to make consumers get to know compositions and origin of products, and in case of quality problem, enterprises (organizations or institutions) can rapidly define ranges of product, provide relevant record to confirm the traceability depth, and determine the time, place, traceable unit and liable entity of quality problem of agricultural products, to provide basis for solving problem.

Currently, most mature ASCTSs adopt bar code or Radio Frequency Identification (RFID) technology. They collect, store and transmit information of the entire supply chain of agricultural products, and store the information relevant to agricultural products in bar codes or RFID tags. Yang Xinting *et al.* developed the process coded quality traceability system for aquaculture products[1]. Zeng Liancheng *et al.* stored traceability information of agricultural product production by UFH RFID tags, and achieved the trace of agricultural products without the help of network[2]. In the above two cases, production information of agricultural products is identified through codes. For trace of processing, transportation, and sales, enterprises have to inquire through the original purchase and shipping records, which is good in tracing efficiency of production of agricultural products. However, since the storage capacity of RFID tags is limited, when tracing agricultural products, the system will only trace the relevant links, and it will fail to diagnose information of other links. If the supply chain is too huge, it certainly will lead to efficiency reduction of the entire traceability system. When problem occurs in other links of supply chain, such traceability mechanism will fail to satisfy the requirement. Then, it needs a technology to integrate many technologies, to diagnose according to change of environment, and automatically adjust and make policy according to system target to achieve traceability of agricultural products, and Agent technology just has such ability. Every node of ASCTS is independent and integrated together as per tracing demand and task of supply chain, to jointly complete specific targets. Since the tasks change with demands, the network rapidly recombines along with tasks. It is a typical distributed system. Using Agent technology, it is able to make the entire system highly reconfigurable. Here, Multi-Agent technology is applied into Agricultural Supply Chain Traceability System, to have a preliminary study on the model and realization method of this system.

1 Application of Agent technology in ASCTS

Up until now, the research of ASCTS is mainly relied on bar code or radio frequency technology to carry out quality tracing of agricultural products. There are few researches of Agent technology directly applied in ASCTS. Only few scholars put forward this idea. Ma Yong *et al.* discussed Agent-based ASCTS mechanism, controlled the nodal information in supply chain from the source. They collected information of all links through arranging place of production, purchase, sale, and circulation Agent, and then gathered to information detection Agent, which filters the collected information as per tracing tasks to obtain required information[3]. For application of Agent technology in ASCTS, major researches are carried out on information coordination of supply chain. Ioannis Manikas pointed out that an efficient traceability system must be provided with proper rules to collect and store huge information in each phase of the supply chain, and to realize traceability of food supply chain through building a model[4]. Moises Resende-Filho put forward a principal-agent model for investigating traceability system's incentives on food safety. His research shows that more reliable traceability system will restrict suppliers' acts to enhance the food safety[5]. Wang Shiqing *et al.* used Multi-agent technology to build model and simulate for supply chain system of manufacturing industry. Their system model can ob-

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jectively describe complex system actions of supply chain and have higher efficiency and stability[6]. Zhang Qing *et al.* carried out model building and simulation for information coordination of production and policy making in the supply chain made up of single supplier, single manufacturer and single seller. The results prove that this Agent system is feasible in providing policy support for managers[7]. Zhang Zhiyong *et al.* researched the information coordination mechanism of cold chain logistics system. They established an MAS-based three level Agent structural model, which adopts Multi-agent system to have a global coordination and a centralized control of every node. This system features high robustness and stability[8]. Han Rendong *et al.* put forward a simulation and model building method based on Multi-agent technology according to such characteristics as complexity and unstability of military logistics system. At the same time of manifesting logistics flow, this model also reflects dynamic feature of system[9].

The implementation of ASCTS and enhancement of traceability, we must use many modern technological means to achieve the optimum effect. Researches have shown that Agent system can be the first choice in solving complex problems, because Agent system effectively integrates many technologies. Besides, Agent also provides new research ideas and methods for ASCTS. The above situations indicate that most researches are still in the phase of theoretical demonstration and mainly focused on system modeling and simulation, and the research of application of Agent technology in ASCTS is still at the starting stage.

2 ASCTS entity model

ASCTS is a distributed system formed by such independent or semi-independent economic entities as production, processing, delivery, distribution and retailing, *etc.* Here, a typical ASCTS is used as research object and establish ASCTS entity model shown in Fig. 1. This system includes four entity levels, namely, producer, delivery center, distributer and retailer. We introduce several entities into each level of entity on the basis of the supply chain system in real world. The producer produces agricultural products, packages and transports products as per orders; the delivery center collects, packages, stores and transports agricultural products; the distributer breaks down, stores and transports, and distributes products; and retailer breaks down and sells products. In this system, each entity includes many business links, and each link stores a lot of relevant information. Batches of agricultural products derive new batches through collection, decomposition, change, and move, and upstream and downstream members form extremely complicated connected relation. The material flow of this system is single direction, and the information flow is dual direction. The dual directional information flow includes circulation information and traceability information.

ASCTS requires that in case of product problem, it is able to reversely trace the source and every links. Besides, once the problem link is determined, the system can trace the flow direction of the same batch product, so as to reduce harm to consumers. This simplification of modeling for ASCTS not only can truly reflect the interaction between entities of supply chain and each Agent, but also can reflect change of each entity in real world through change of Agent attribute.

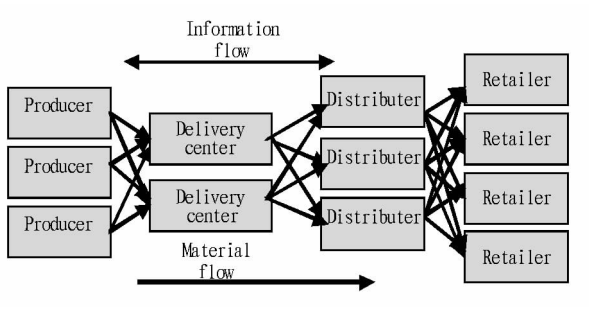

Fig. 1 Entity model of agricultural product supply chain traceability

3 Mechanism of MAS based ASCTS

Agricultural product supply chain can be deemed as a network consisting of a group of nodes and relevant activities. The nodes can be production, processing, delivery, distribution and sales enterprises or departments of these enterprises participating in activities of supply chain. As to interconnection of information system, each node of supply chain traceability system has its own information system and each system establishes its own system. They can not have a good interaction of information sharing and business, while Agent technology is an effective way to realize the interconnection between heterogeneous systems. From the point of the modular management, the entire supply chain traceability system can be deemed as a unitary big system. Each node is a module of this big system, and each module is mutually independent but needs coordinated work. It is unnecessary for each module to find out the way of other modules achieve. It is only necessary to know what it can do and how it is called. In this context, the Agent technology is the optimum tool.

MAS based agricultural product supply chain traceability system can be traced from end of supply chain. It is possible to set independent MAS subsystems (including Production MAS, Delivery MAS, Distribution MAS and Retailing MAS) of each node in the supply chain, to keep the connection of each node, so as to ensure the accuracy and timeliness of information acquisition. Each MAS subsystem represents an entity node of the supply chain, and it is a federal structural model centered on coordinating Agent. Fig. 2 is an ASCTS based on MAS, the coordination Agent is responsible for coordinating work of local Agent subsystem. This system controls the product information of each entity node from the source. Each entity keeps connection through coordination Agent to achieve a dual direction transmission of information. Besides, this system features incomparable advantage in interaction of each node compared with traditional traceability system. It can realize real-time information collection and intelligent processing, and make quality traceability department can obtain product information in time.

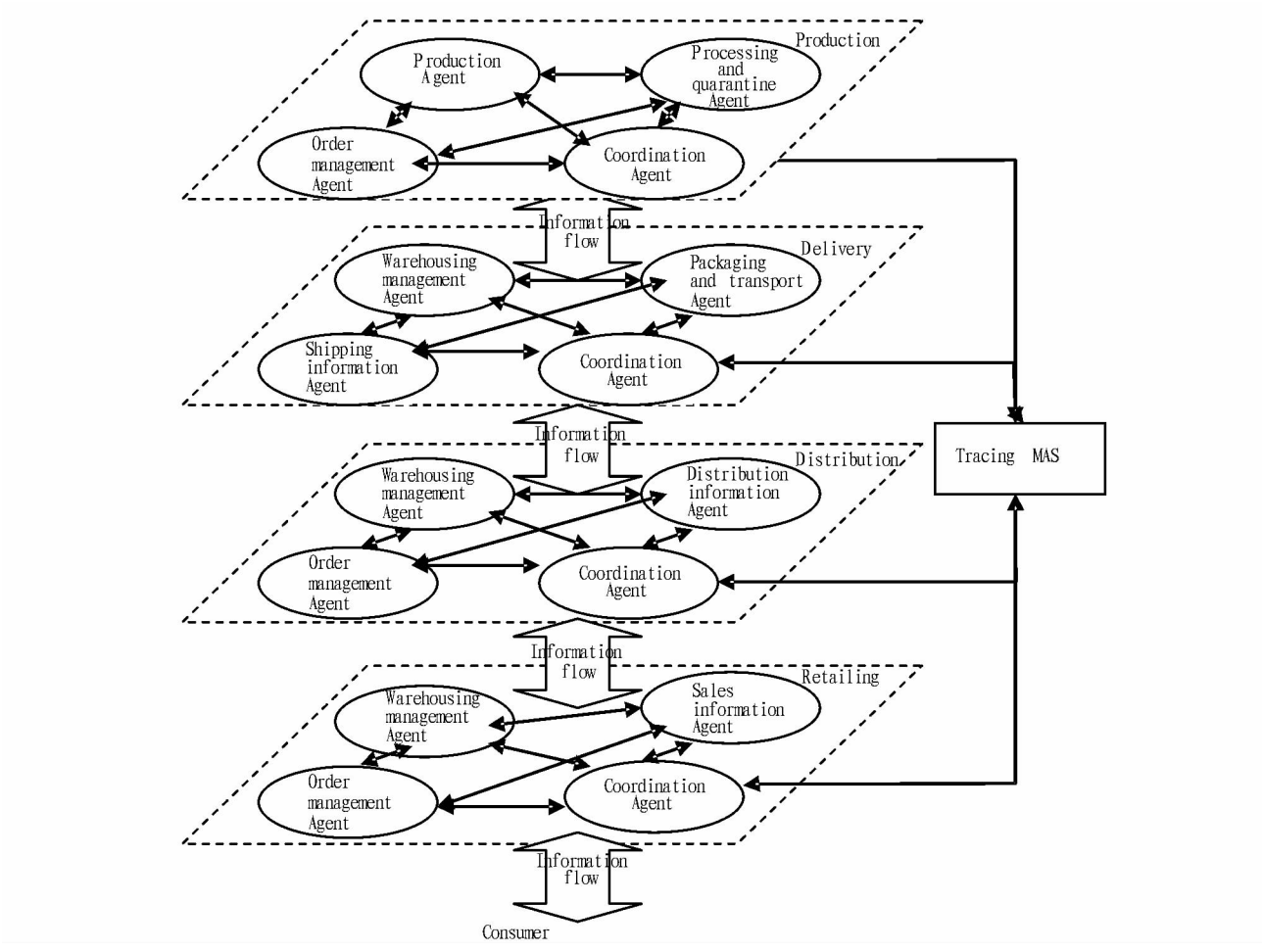

Fig. 2 Structure of ASCTS based on MAS

3.1 Production MAS Agricultural product entity can be agricultural production base, large scale farm, and large planting and cultivation organizations. It realizes information management in production process. Here, the Multi-agent system is simplified into order management Agent, production process Agent, and quarantine information Agent. The order management Agent is responsible for gathering orders and arranging packaging tasks. The production Agent takes charge of collecting information of planting land, breeding, fertilizer application, disease and insect pest prevention and control. The processing and quarantine Agent is responsible for connecting information of agricultural product processing, residues of pesticide, quarantine, and packaging, *etc.* The coordination Agent transmits information of product batches to the delivery MAS, and provides basis for tracing products. When the coordination Agent receives task of tracing certain batch or order of products, it will analyze the tracing target, assign one or several Agent(s) to collect relevant information, and gather the information, finally to make the order management Agent draw the same batch of product to circulate, so as to improve the integrity of traceability information.

3.2 Delivery MAS The delivery MAS consists of warehousing management Agent, packaging and transport Agent, and shipping information Agent. The warehousing management Agent is responsible for collecting storage position, time and temperature, and ventilation information of product. The shipping information Agent recombines the shipping documents in the flow direction, and issues unpacking and integration orders to packaging and transport Agent and generate new batches. The packaging and transport Agent conducts packaging and transport of different origins and types as per orders, mainly including packaging material, loading and unloading information. The coordination Agent in delivery MAS executes two tasks. One is to transmit the product batch to downstream. The other is to analyze the traceability task and order other Agents to collect information. At the same time, it orders the shipping information Agent to determine its source, so as to trace the product origin.

3.3 Distribution MAS The distribution MAS include warehousing management Agent, distribution information Agent, and order management Agent, *etc.* The warehousing management Agent is responsible for collecting information of quality guarantee period, storage position, storage manner and volume of stock. The distribution information Agent takes charge of flow direction of product sales. The order management Agent can generate new order through warehousing information transmitted by warehousing Agent and manage the completed

order (record the completion time of order and product batch, *etc*). The coordination Agent on one hand sends the product batch to order management Agent. On the other hand, it decomposes the tracing task into two subtasks: the warehousing management Agent collects information, and the distribution information Agent determines the flow direction of the same batch of product.

3.4 Retailing MAS Generally, there are two types of agricultural product retailers: supermarket and individual peddler. Due to self limitation, the individual peddlers have no ability to establish an information system. Thus, in this model, they are deemed as end of supply chain, namely, consumers. Supermarket has well established information system, excellent information qualification, so it is able to establish Multiple Agent system. The retailing MAS includes warehousing management Agent, order management Agent (both are the same as that of distribution entity), sales information Agent (responsible for collecting information of sales time and quantity of products). The coordination Agent is responsible for coordinating Agent subsystems in completing routine works and tracing tasks.

Multi-agent based ASCTS is mainly to collect information and diagnose problem, and communicate with coordination Agent of each entity node through a global Agent.

4 Agricultural product tracing algorithm based on message/dialogue communication mechanism

The message/dialogue communication is the basis for realizing flexible and complex coordination strategy. Each Agent exchanges messages with specified protocol to establish communication and coordination mechanism[10]. The transmission Agent sends specific message to another Agent. If this Agent is not the corresponding one, it can not read this message. This mechanism is introduced to agricultural product supply chain traceability system to achieve Agent communication between entities. In addition, apart from receiving product tracing task, the coordination Agent in each entity (except starting end of supply chain), it is possible to trace the flow direction. Through this system, it not only can trace the product from source to end for diagnosis, including production, processing, packaging, transport and warehousing, *etc*. For products with problem determined, it is able to trace from the problem link to downstream links, collect information of flow direction of this batch of products, to prevent harm spreading. Take the retailing MAS and delivery MAS as examples, the algorithm of MAS subsystems are introduced as follows:

4.1 Tracing algorithm of retailing MAS

(1) The traceability system assigns tracing task, transmits the task to retailer (suppose the batch of traced product as *bn*, the task is *M*, the product batch of traced product is *cn*, the traced task is *N*, the same below).

(2) The retailer coordination Agent analyzes the task. In case of *M*, it executes (3); in case of *N*, it executes (5).

(3) The warehousing Agent collects storage information of *bn* and sends it to traceability system, the communication Agent of which takes the information to upstream diagnosis module. In case of no problem source, it will continue to issue tracing order to retailer, the coordination Agent of retailer sends the tracing task to coordination Agent of distributor according to upstream distributor information provided by order Agent, then the algorithm completes.

(4) If the determined problem link is retailer, it will send tracing task.

(5) The coordination Agent actuates sales information Agent to collect sales information of *cn*. At the same time, the stock Agent also collects stock information of *cn* and sends to traceability system. Then, the algorithm completes.

4.2 Tracing algorithm of delivery MAS

(1) The coordination Agent receives the task. In case of *M*, it executes (2); in case of *N*, it executes (4).

(2) The warehousing Agent collects storage information of *bn*. The packaging Agent collects packaging information. The coordination Agent gathers and filters information, and sends the information to traceability for diagnosis. If no problem source is found, it will issue an order to coordination Agent of producer to continue to trace, then the algorithm finishes.

(3) If the problem link is determined, the shipping Agent will determine the flow direction of *cn* (or the downstream entity), and issue the tracing task. (4) The shipping Agent and packaging Agent determine flow direction of *cn*, and transmit tracing task to the downward entity.

Since distribution MAS and retailing MAS algorithms are similar, while the tracing algorithm for product origin is relatively simple, so here we omit this part.

5 Conclusions

As a developing technology, Agent technology is becoming more and more mature in the application of traffic control and e-commerce. The utilization of Agent technology in agricultural product supply chain traceability system is a new research direction. It makes the tracing of agricultural products changing to intelligent one, expanding depth and accuracy of traceability, and will provide certain theoretical and practical values for ensuring quality safety of agricultural products. Since there are a great variety of agricultural products, many agricultural product supply chain systems are not quite identical. Therefore, the research of agricultural product supply chain traceability system under MAS theory should be based on existing traceability system. To truly implement agricultural product quality tracing, it requires support of enterprises, government and competent authorities, and consumers. Besides, it is required to provide powerful support in social system. Furthermore, relevant researches are just starting. The next work is to build models and conduct simulation test for the system, and to constantly make improvement.

References

[1] YANG XT, SUN CH, QIAN JP, *et al.* Construction and implementation of fishery product quality traceability system based on the flow code of aquaculture[J]. Transactions of the Chinese Society of Agricultural Engineering, 2008, 24(2): 159-163. (in Chinese).

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rise, increasing the daily consumption expenditure of urban residents, but farmers complain that they do not make money and get more benefits, the main reason of which is that at present, the cost of circulation in China is too high, and distributors and retailers get excessive profits, generating a phenomenon of "the two ends vociferating but the middle end laughing". Therefore, first, we should establish modern agricultural circulation system, accelerate the infrastructure building of circulation of agricultural products, open up the green channel for agricultural products, abolish all kinds of unreasonable charges, integrate the existing transportation resources of roads, railways, ports and so on, coordinate interest relations of all regions, and reduce the circulation costs of agricultural products to the extreme. Second, we should strengthen the supply chain management in the circulation process of agricultural products, establish modern digital information-based and technology-based distribution system of agricultural products, promote efficiency of processing, refrigeration, storage, transportation, and distribution, and effectively reduce natural and man-made loss rate of agricultural products in circulation links after production.

3.3 Better organize agricultural cooperation and strengthen farmers' market price game ability Through the establishment of various types of agricultural cooperative organizations, we are to change the existing decentralized, small-scale, and non-organization state of agricultural production, organize farmers, connect small rural households and big supermarkets, promote farmers' market price bargaining and negotiating power, and reduce the risk losses arising from information asymmetry and irresistible power of agricultural production. In the mean time, the government should encourage and support rural cooperative organizations, offer preferential policies for rural cooperative organizations in the process of self-built distribution channels, guide the farmers to build direct marketing connection of terminal supermarket, simplify and shorten the circulation link, and reduce distribution costs, so that farmers fully enjoy the returns brought by the circulation appreciation of agricultural products, and the farmers organized truly become market game subject with competitiveness, to promote healthy and rapid development of agriculture.

3.4 Vigorously promote agricultural technology, reinforce agricultural technology training and reduce reliance of agricultural production on labour forces At present, a large number of young labour forces in rural areas flow out, and supply and demand contradiction of agricultural labour is increasingly prominent. We should vigorously promote agricultural science and technology, change the extensive mode of production that China's agriculture excessively depends on inputs of labour forces, and rely on agricultural technology to change agricultural growth mode. Through the development of vocational education, adult education and a variety of short-term trainings, we should improve farmers' agricultural professional skills, fully use agricultural technical schools and other agricultural training resources as well as modern information network, disseminate information of agricultural technology, organize scientific and technological personnel to go to rural areas to impart scientific knowledge, carry out various forms of popular culture and education, science and technology popularization activities, improve the quality of agricultural workers, and improve technological content in agricultural products. We should truly realize taking science and technology as the first agricultural productivity, improve agricultural productivity, gradually change the status quo of "eating dependent on the weather, farming dependent on human", achieve stable and continuous increase in farmers' income, change the status of urban-rural dual structure, and achieve balanced regional development.

References

[1] ZHANG WY. Game theory and information economics[M]. Shanghai: Joint Publishing Company, 2004. (in Chinese).

[2] WANG L. Study on game model and economic quality of cooperative profit in three-stage supply chain[J]. Operations Research and Management Science, 2009(4): 67-72. (in Chinese).

[3] ZHAO LF. Integration strategy of agricultural supply chain[J]. Commercial Times, 2010(2): 33-35. (in Chinese).

[4] SONG LL. Causes of recent consumption of agricultural prices continued to rise[J]. Agricultural Economy, 2010(11): 73-75. (in Chinese).

[5] JI LG. The key problems in agricultural product circulation and the solution way[J]. China Business and Market, 2011(7): 18-20. (in Chinese).

[6] WANG HM. The analysis on influence of farm products price fluctuations under the national policy—a case study on cotton[J]. On Economic Problems, 2009(5): 83-85. (in Chinese).

[7] WAN DH. Preliminary analysis of some agricultural products prices rising in recently[J]. The World of Survey and Research, 2010(3): 3-4. (in Chinese).

[8] ZHANG LH. Analysis of the impact of contract of farmers and retailers model on agricultural prices[J]. Price: Theory & Practice, 2010(8): 78-79. (in Chinese).

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[2] ZENG LC, SHEN Y, PENG JH, *et al*. Study on traceability system of farm products based on UHF RFID tags[J]. Journal of Anhui Agricultural Sciences, 2010, 38(26): 14734-14735, 14740. (in Chinese).

[3] MA Y, ZHU YP. Research on agricultural product traceability system based on Agent[J]. Journal of Agricultural Mechanization Research, 2010(7): 193-196. (in Chinese).

[4] IOANNIS MANIKAS, BASIL MANOS. Design of an integrated supply chain model for supporting traceability of dairy products[J]. International Journal of Dairy Technology, 2008(62): 126-140.

[5] MOISES RESENDE FILHO. A principal-agent model for investigating traceability system incentives on food safety[R]. The 105th EAAE Seminar International Marketing and International Trade of Quality Food Products, 2007: 127-138.

[6] WANG SQ, LI CB. Multi-Agent-based supply chain model and simulation[J]. Computer Engineering and Design, 2010, 31(5): 1081-1084. (in Chinese).

[7] ZHANG Q, LIU ZX. Multi-agent-based modeling and simulation for information coordination in supply chain[J]. Application Research of Computers, 2009, 26(10): 3709-3711. (in Chinese).

[8] ZHANG ZY, LIU C, YANG L. Study on the cold-chain logistics system coordination mechanism based on MAS[J]. Science and Technology of Food Industry, 2010, 31(5): 387-390, 393. (in Chinese).

[9] HAN RD, LIU KC, JU YB, *et al*. Method of multi-agent based simulation modeling for military logistics[J]. Application Research of Computers, 2010, 27(5): 1756-1759. (in Chinese).

[10] CAI ZX, XU GY. Artificial intelligence and its application[M]. Beijing: Tsinghua University Press, 2010: 325-326. (in Chinese).