Abstract—In order to achieve an accurate expression and effective sharing about the hazards monitoring and managing knowledge between the upstream and downstream of the cold chain, the paper establish a HACCP ontology model of the cold chain on the basis of analyzing and summarizing general business processes of the cold chain and HACCP management system. In the experiment, we implement the HACCP ontology of the cold chain according to the background knowledge of the application, and achieve automatic identification of the concept-instance by applying the SWRL inference rules and HermiT inference engine, and share business knowledge among the different steps in the cold chain. The results show that the model can be applied to model the HACCP management knowledge to improve the management efficiency of the cold chain hazard monitoring. However, due to the complexity of the cold chain monitoring and managing, the model still requires combining with the knowledge in the field of specific domain in the processes of practical application to further improve.

Keywords- cold chain logistics; ontology; HACCP; knowledge description; knowledge reasoning;

I. INTRODUCTION

With food safety incidents increasing significant all over the world, the food safety surveillance has become a hot topic with high profile. In order to ensure that the food is safe and controllable in the whole process, In 1997, the CodexAlimentarius Commission announced “International Recommended Operating Standard The Profile Of Food Hygiene”, the standard stipulates critical control measure at each stage form primary production to final consumption, and use the Hazard Analysis and Critical Control Points (HACCP) method to make the food safe.

HACCP has become internationally recognized and accepted as the food safety assurance system, it is widely used in food, pharmaceuticals and other products in the cold chain business links. However, the construction of cold chain logistics needs a huge investment, many food producing and processing enterprises trend to use the third-party cold chain logistics service[1,2], how to ensure the integrity of the multi-party cold chain logistics safety monitoring is becoming an important research field in recent years. An information architecture was analyzed and established for third-party refrigerated warehousing companies to improve operational efficiency and reliability of third-party refrigerated storage[3]. A framework based on Delphi-AHP-TOPSIS method was proposed to assess the effects and defects during the cold chain operating procedure, and it point out that the most difficult is to collect key information in the process of practical application [4]. According to relevant studies, the key issue to make sure that the entire cold chain process safety is to ensure that the critical information of monitoring and managing during every processes in the cold chain is flowing and sharing.

This paper attempts to use the Semantic Web Ontology language, OWL2DL establish cold chain HACCP ontology, CC-HACCP Ontology, in order to compensate for the deficiencies in the ability of rule description and ratiocinate semantic, the model also use the production rules based on SWRL and logic-based inference engine, realize the formal representation and inference of the knowledge, such as service features, experience, and rules. The model can be applied to the knowledge semantic describe and share about the cold chain hazards monitoring and managing to help managers improve the cold chain HACCP management system, and the correct implementation of HACCP in all aspects of the cold chain.

II. HACCP

Hazard analysis and critical control points, referred to as HACCP, is made up of two parts of Hazard Analysis and Critical Control Point. The core idea of the HACCP management system is to analysis the raw materials, production processes and the impact of product safety human factors, to identify key processes in the machining process, to establish and perfect monitoring program and monitoring standard, and to take the standardize and corrective measures. HACCP’s purpose is to eliminate the possible occurrence of food safety hazards in the production process, rather than by the post test to ensure the safety of food. It consists of seven basic elements [5]: the hazard analysis (HA), and to determine the potential hazards in each stage of the food production, including raw materials processing, manufacturing, storage products, sales and other processes; the determination of the critical...
control points (CCP), it can be a controlled point, step or method through controlling the food potential hazards can be prevented, eliminated to an acceptable level; the key limit value (CL), for each of the CCP need to determine a standard value, to ensure that each CCP limit value in the security value; establishing the CCP monitoring program, set up and take effective corrective measures; establish a verification procedures, including the confirmation of the plan, CCP verification and measures; establish a verification procedures, including monitoring program; set up and take effective corrective measures, value in the security value; establishing the CCP determine a standard value, to ensure that each CCP limit value CL, corrective measures CA, verification VE, and records RE.

Cold chain subject concept CC_Role. According to the analysis of the cold chain of business process. In this paper, cold chain is divided for the following roles: Raw Material Supplier, producer, Logistics Service Provider, Wholesaler and Retailer. The concept of CC_Cargo can be divided into two types of Frozen_Cargo and Refrigerated_Cargo by storage temperature range. Where the frozen type of goods is required to store, transport, wholesale and distribute in the following -18°C. While cold type of goods is required in the following 7°C. Business process concept CC_Step. Step is the abstract in the concrete steps of the cold chain business process, Step are responsible for the implementation and operation by CC_Role.

Monitoring object information carrier concept CC_Proof, monitoring object information carrier, is the important evidence used to detect whether meet the key limit value, the fact may include: the goods state with appearance of the cargo and the packing seal, official proof materials such as proof of inspection and quarantine or non-epidemic areas, cargo loading and unloading records and goods out of warehouse ledger and other business operation records, warehousing and transportation environment temperature records and the relevant records (RE) produced by HACCP system.

B. Basic Properties of CC-HACCP

The relationship of the cold chain HACCP ontology is mainly divided into two kinds of object attributes and data attributes. Object properties mainly describe the relationship between the concepts, the scope and range are concepts, part of CC-HACCP's objects properties are show in Tab.1.

<table>
<thead>
<tr>
<th>Objects Properties</th>
<th>Domain</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>next_step</td>
<td>CC_Step</td>
<td>CC_Step</td>
</tr>
<tr>
<td>is_charged_by</td>
<td>CC_Step</td>
<td>CC_Role</td>
</tr>
<tr>
<td>handle_cargo</td>
<td>CC_Step</td>
<td>CC_Cargo</td>
</tr>
<tr>
<td>cause_by</td>
<td>HA</td>
<td>CL</td>
</tr>
<tr>
<td>has_CA</td>
<td>CL</td>
<td>CA</td>
</tr>
</tbody>
</table>

data properties describe the relationship between the concept and the data type, the scope is concept, the range is related data types, including: integer, string, float, Boolean, symbol, XML scheme datatype and so on, part of CC-HACCP's data properties are show in Tab.2.
increase the following concepts: appearance and organization form. The examination index and sensory parameters, such as usually adopts the temperature, time, humidity, the actual knowledge of the business, the key limit (CL) documentation. According to the above knowledge can value, and the monitoring process measure or observe the key control points of key limit, monitoring measures need to be in a planned way to system, for each key control point must provide critical

prefixing them with a question mark "?x". Due to space

Variables are indicated using the standard convention of

consequent", where both antecedent and consequent are

combinations of atoms written “atom1, atom2, … atom3”.

Variables are indicated using the standard convention of

prefixing them with a question mark “?x”. Due to space limitations, this article only list the following three rules.

- **Step Generate Proof Rule**
  If cold chain in a step implemented a monitoring measures cm and cm have records(re), and re can be used to test a critical limit (cl), then should be consider as a instance of CC_Proof, and is generated in the step. In fact, the deduction that the re is a instance of CC_proof inference is not obtained from the direct inference of the rule, but because the rules using the step 'object attributes step_generate_proof', which range is CC_proof. So we can infer that the re is an instance of the proof of concept CC_proof. The rules are described as follows:

\[
\text{has CM(?step, ?cm), has RE(?cm, ?re), CL proved by(?cl, ?re) } \\
\rightarrow \text{ step generate proof(?step, ?re)}
\]

- **Step Submit Proof Rule**
  If cold chain in a steps step1 implemented a monitoring measures cm, and cm monitoring key limit value of cl and proven track record by the monitoring object information carrier proof, and step2 and step1 are not the same steps, and in the cold chain process, step1 is after step2, then step2 need to submit proof which generated in step2 toits subsequent business steps. Because of the next step is transitive, the next step(step2, step1) is true even if the step1 is not directly following the step2. The rules are described as follows:

\[
\text{has CM(?step, ?cm), monitor CL(?cm, ?cl), } \\
\text{CL proved by(?cl, ?proof), proof from step(?step, ?proof), } \\
\text{DifferentFrom (?step1, ?step2), next step(?step2, ?step3) } \\
\rightarrow \text{ step submit proof(?step2, ?proof)}
\]

- **Step Deliver Proof Rule**
  Based on the Rule of Step Submit Proof Rule expression, if there is step3 which is different among step1 and step2, and step3 is intermediate step between Step2 and step1, then step3 need to deliver the proof. The rules are described as follows:

\[
\text{has CM(?step1, ?cm), } \\
\text{monitor CL(?cm, ?cl), CL proved by(?cl, ?proof), } \\
\text{proof from step(?step, ?proof), ?step2), DifferentFrom(?step1, ?step2), } \\
\text{DifferentFrom(?step2, ?step3), CC Step(?step3), } \\
\text{next step(?step2, ?step3), next step(?step3, ?step1) } \\
\rightarrow \text{ step deliver proof(?step3, ?proof)}
\]

### IV. EXPERIMENT

The case’s background is the cold chain of eating oyster products. In this case, cold chain process include: Live oyster fishing, live oysters transportation, raw material receiving, production and processing. Live oysters supplier did not establish the HACCP system, The third cold chain logistics service provider and the producer preliminary establishes HACCP management system, but the information and knowledge is not shared, such as, the logistics service provider does not know what information is required by the producer.

#### A. Experiment 1: CC-HACCP Ontology Building

Combed irrelevant standards, CC-HACCP based on OWL 2 DL language was built by using the ontology tool protege5, the class structure is shown in Fig.1.
B. Experiment 2: Inference Based on CC-HACCP

The inference engine HermiT (version 1.3.8) reasoning, which accord to the definition of CC-HACCP, constraints and characteristics of properties, was used to realize the concept of consistent test and instance automatic identification. Such as an instance of the concept of CC Step, "step_of_live_oyster_transportation" was identified as the critical control points (CCP) and the "Risk Step" automatically. The reasoning result is shown in area 1 of Fig.2.

At the same time, inference machine according to the inference rules presented in the previous paper, deduce the new object property assertions between instances of various concepts, which is unknown before the reasoning, such as: "step_of_live_oyster_transportation" which is an instance of CC Step get some object properties after the reasoning, the result is shown in the area 2 of Fig.2.

C. Experimental Summary

Experimental results show that CC-HACCP ontology can be well used to build the smantic knowledge model in the actual business process of the cold chain, which will help the cold chain manager to optimize the HACCP system in multiparty participation cold chain, and share the HACCP knowledge.

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