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Ontology Based Monitoring Of Seafood Quality And Modeling Of Acceptance Criteria Of Seafood Using Semantic Web Rule Language

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Abstract

The export of seafood is extremely important in many countries' economic situations. Most of the developed fish-importing countries have implemented stringent quality and sanitary standards for fishery goods. To preserve consumer safety and health, strong food control procedures are required. But most of the seafood enterprises use manual quality assessment techniques to evaluate and maintain the safety and quality of their products. As a result, we propose a computer-based system that would store the quality assessment guidelines and test values in ontology and then employ acceptance criteria for tests encoded in ontology language to meet food safety requirements. Semantic Web Rule Language (SWRL) is used to model the acceptance criteria of seafood quality tests. The ontology is implemented using Protégé 5.5.0. The Pellet Reasoner is used to infer new information from the ontology. The paper concludes by demonstrating the classification of different instances (samples) of Crustaceans into Accepted/Not_Accepted classes automatically by the reasoner.

Keywords: ontology, seafood ontology, SWRL, OWL, seafood quality assurance

Introduction

In recent decades, food hygiene has become a big issue, and maintaining food quality is the very first step toward calling light to a country's fisheries. To ensure the safety and health of consumers, strong food control systems are required. They're also important for allowing governments to guarantee the security and quality of their foods into global trade, as well as ensuring that imported foods meet national standards [1]. Food control systems must be developed, and risk-based food control measures must be implemented and enforced in both importing and exporting countries [1]. It is difficult and costly to detect the food safety and quality issues, as such issues can arise at any point in the food supply chain. To improve food safety and quality, a very well, precautionary strategy that controls processes in a food supply chain is advised [1]. Hazard Analysis Critical Control Point (HACCP), Good Manufacturing Practice (GMP), and Good Hygiene Practice (GHP) are examples of food regulations that attempt to ensure a specific level of quality.

According to the study of Al-Busaidi et al. [2], seafood items in the supply chain are frequently subjected to extensive management and dissemination processes before reaching the customers, a problem that many developing countries experience. Because seafood items are frequently perishable, their safety is jeopardized if they are not properly managed. Chemicals residues (such as Nitrofurans, Chloramphenicol etc.), microbial contaminants (such as Salmonella, Staphylococcus etc.) and parasites are the agents that pose severe threats to seafood [3]. HACCP system includes the acceptance criteria to distinguish acceptable from non-acceptable products.

An ontology is a model that represents a domain's common and shared understanding [4]. Ontology is concerned with ways of encoding knowledge such that machines may make accurate deductions and conclusions from it. In general, an ontology consists of a taxonomy and inference rules that allow the ontology's consistency to be checked and new information to be inferred [4]. The Web Ontology Language (OWL) was created because of the W3 Consortium's recognition of the need for a language that would allow for enhanced machine readability of web information [4]. The meaning of terminologies used in web documents can be formally described using OWL. It defines classes and properties related to the domain entities, define instances of the classes, establish relationships between the entities, and conduct reasoning about the classes and the instances.

SWRL is an OWL-based rule language with a lot of flexibility [5]. Users can write rules that can be represented as OWL concepts with SWRL, allowing for more complex deductive reasoning than is feasible with OWL alone. [5]. SWRL is semantically like OWL in that it is based on description logic and provides strong formal assurances while inferring [5]. For Horn-like rules, SWRL supports a high-level abstract syntax [6]. SWRL rule engine bridge retrieves SWRL rules and asserted knowledge from ontologies and passes them to the rule engine for execution [7]. Inferred knowledge can be committed to an ontology or displayed to users through an interface [7].

Currently, the lab technologists refer the test standards and guidelines manually to ensure the validity of the tests. Depending on the product, and the country of export, the criteria vary. Different quality and safety requirements and policies enforced by importers are, nevertheless, one of the most important challenges facing exporters [8]. It is hard to remember the guidelines of every country and every test. So, we proposed a computer-based system to store the guidelines and test values in ontology and later use the acceptance criteria of tests encoded in ontology language to meet the food safety. This research paper focusses on the modelling of the HACCP acceptance criteria of seafood quality checking tests using Semantic Web Rule Language (SWRL) [9].

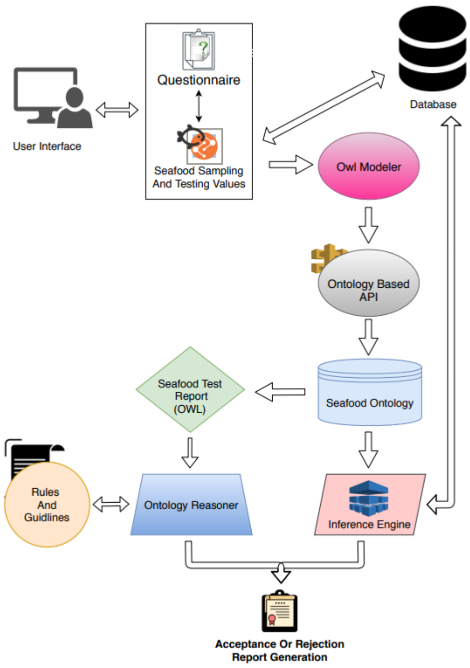
The rest of the paper is outlined as follows: - Materials and methods is presented in Section 2. This section includes the proposed architecture, seafood ontology design, and modelling of test guidelines using SWRL. Section 3 presents the results and discussion in which two instances of Crustaceans sample is demonstrated. Conclusion is presented in Section 4 followed by References.

Materials and Methods

Architecture

Several factors are examined by lab technicians during quality tests conducted on seafood at various stages of processing (either in-company or government-approved labs). If the test results do not meet the quality requirements of the exporting country (either EU or non-EU countries), the seafood may be rejected. Fig. 1 depicts the basic architecture of our proposed system.

Figure 1.Proposed architecture



This model follows the method of collecting test results of seafood samples from the user through the user interface, which is then compared with the guidelines to provide the result of acceptance or rejection of seafood. A questionnaire is used to collect the test results of seafood samples and it is passed on to the OWL modeler and saved in the database. The ontology-based API helps to input the result into Seafood Ontology. Each test result is an OWL file with a description of the parameters tested with result.

The ontology reasoner then processes the OWL file and provide the conditions to determine the correctness of superclass/subclasses relationship and existence of instances for a class. Ontology reasoner checks the stability of the ontology and compute the ontology class hierarchy automatically. The rule-based reasoner is a potential strategy for improving ontology-based models' inference capabilities, and it makes considerable contributions when semantic queries are performed [10]. The reasoner determines whether all the concepts are satisfiable.

The test specification/rules in guidelines are represented using SWRL [9]. SWRL rules along with relevant OWL knowledge are transferred to the inference engine to execute the rules. The knowledge surmised by the inference engine is transferred to the existing OWL knowledge, which thereby produce a semantic seafood quality report. This test result report aids in determining the quality of seafood and the likelihood of acceptance or rejection.

Modeling of Seafood Ontology

Fig. 2 displays the taxonomy of subclasses of Fish concept. Protégé, the free open-source editor is used to develop the ontology [11]. The complete development of seafood ontology is presented in our research paper [12]. This research paper concentrates on the modelling of HACCP test guidelines in SWRL.

Figure 2.Taxonomy (Sherimon et al., 2021)

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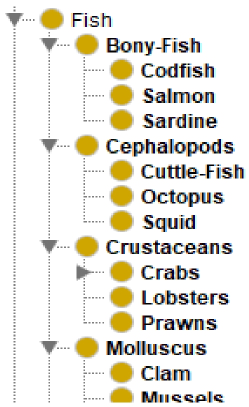

Modeling Test Guidelines as SWRL Rules

SWRL is a rule language based on OWL that is expressive [9]. SWRL use Horn clause, more officially stated as implication. An implication is the result of combining an antecedent (body) with a consequent (result) (head). The antecedents and consequents of an SWRL rule are constructed using atoms. Unary predicates (class names), binary predicates (data and object properties), equality, built-ins, and other elements make up each atom [13]. To cause all the atoms in the consequent to be true, all the atoms in the antecedent must be true at the same time. The SWRL rules are supported by the Pellet reasoning engine [14]. Pellet is the first OWL-DL reasoner to enable reasoning with individuals, user-defined datatypes, and ontology troubleshooting in a substantial way [14]. Pellet is integrated into Protégé, and it support decidable reasoning over OWL [13].

Table 1 presents the different tests (microbiological, antibiotic etc.) required by Crustaceans (frozen) for export to Europe. As stated in Table 1, there are a total of 28+ tests performed on Crustaceans. The values of these tests are input to the system by the technologists. These test values are then compared with the standard guidelines to check the limits.

The basic rule that determines whether a sample of crustacean is acceptable is Rule 1. If all the test results are correct, the final output will be "ACCEPTED", and the instance will be automatically classified under the class 'Accepted_crab'.

Rule 1:

Crustaceans(?x) ∧ acceptance-of-the-product-by-ecoli-value (?x, true) ∧ acceptance-of-the-product-by-Vibrio-Parahaemolyticus (?x,true) ∧ acceptance-of-the-product-by-Staphylococcus (?x, true) ∧ acceptance-of-the-product-by-Salmonellae (?x, true) ∧ acceptance-of-the-product-by-TPC (?x,true) ∧ acceptance-of-the-product-by-Listeria_Mono Cytogenes (?x,true) ∧ acceptance-of-the-product-by-Chloramphenicol (?x,true) ∧ acceptance-of-the-product-by-AOZ (?x,true) ∧ acceptance-of-the-product-by-AMOZ (?x, true) ∧ acceptance-of-the-product-by-AHD (?x,true) ∧ acceptance-of-the-product-by-SEM (?x,true) ∧ acceptance-of-the-product-by-Chlortetracycline (?x,true) ∧ acceptance-of-the-product-by-Oxytetracycline (?x, true) ∧ acceptance-of-the-product-by-Doxycycline (?x, true) ∧ acceptance-of-the-product-by-Tetracycline (?x, true) ∧ acceptance-of-the-product-by-Sulfonamides (?x, true) ∧ acceptance-of-the-product-by-Sulfamethazine (?x, true) ∧ acceptance-of-the-product-by-Sulfadiazine (?x, true) ∧ acceptance-of-the-product-by-Sulfadimethoxine (?x, true) ∧ acceptance-of-the-product-by-Sulfanilamide (?x, true) ∧ acceptance-of-the-product-by-Sulfamerazine (?x,true) ∧ acceptance-of-the-product-by-Sulfamethoxypyridazine (?x, true) ∧ acceptance-of-the-product-by-Sulfamethiazole (?x, true) ∧ acceptance-of-the-product-by-Nitrofurans (?x,true) ∧ acceptance-of-the-product-by-Quinolones (?x, true) ∧acceptance-of-the-product-by-sulfathiazole (?x,true) ∧ acceptance-of-the-product-by-Histamine (?x, true) Accepted_crab(?x) ∧ acceptance-of-the-product (?x, "ACCEPTED")

In the above rule, if all the atoms in the antecedent is true, then both the atoms in the consequent will be true. Separate rules are written to check the truth of each clause in the antecedent. For example, Rule 1.1. is used to check the E-coli test acceptance clause 'acceptance-of-the-product-by-ecoli-value'.

Rule 1.1:

Crustaceans(?x), swrlb:less Than Or Equal(?ecoli_value,20) ∧swrlb:greater Than Or Equal(?ecoli_value, 0) ∧valueOf_E-Coli(?x, ?ecoli_value) → acceptance-of-the-product-by-ecoli-value(?x, true)

Table 1. Standard test specifications for Crustaceans family

Test	Standard values
E coli	(MIN 0 and MAX 20)
Staphylococcus-Aureus	(MIN 0 and MAX 100)
Vibrio-Parahaemolyticus	(MIN 0 and MAX 2.9)
Vibrio-Cholerae	ABSENT
Salmonellae	ABSENT
TPC	(MIN 0 and MAX 5,00,000)
Listeria Monocytogenes	ABSENT
Chloramphenicol	ABSENT
AOZ	ABSENT
AMOZ	ABSENT
AHD	ABSENT
SEM	ABSENT
Chlortetracycline	ABSENT
Oxytetracycline	ABSENT
Doxycycline	ABSENT
Tetracycline	ABSENT
Sulphonamides	ABSENT
Sulfamethazine	ABSENT
Sulfadiazine	ABSENT
Sulfadimethoxine	ABSENT
Sulfanilamide	ABSENT
Sulfamerazine	ABSENT
Sulfamethoxypyridazine	ABSENT
Sulfamethiazole	ABSENT
Nitrofurans	ABSENT

Quinolones	ABSENT
Sulfathiazole	ABSENT
Histamine	ABSENT

Similarly, separate rules are written to check the truth of other clauses in the antecedent.

SWRL rule does not support the logical OR operation, so it is implemented by splitting the disjunction [14]. That means each test rule should be written separately. Rule 2 presents the NOT ACCEPTED case for e-coli test of Crustaceans. Rules 2.1 and 2.2 is used to test the e-coli values.

Rule 2

Crustaceans(?x) ∧ acceptance-of-the-product-by-ecoli-value (?x, false) →Not_Accepted_crab(?x), acceptance-of-the-product(?x, "NOT ACCEPTED")

Rule 2.1

Crustaceans(?x) ∧swrlb:less Than (?ecoli_value,0) ∧valueOf_E-Coli (?x, ?ecoli_value) → acceptance-of-the-product-by-ecoli-value(?x, false)

Rule 2.2

Crustaceans(?x) ∧swrlb:greater Than (?ecoli_value, 20) ∧valueOf_E-Coli(?x, ?ecoli_value) → acceptance-of-the-product-by-ecoli-value(?x, false)

Protége includes SWRLTab, a Protégé-OWL development environment for dealing with SWRL rules (O'Connor et al., 2007). Editing, rule execution, and ontology querying are all supported here (O'Connor et al., 2007). Fig. 3 presents some SWRL rules defined in SWRLTab.

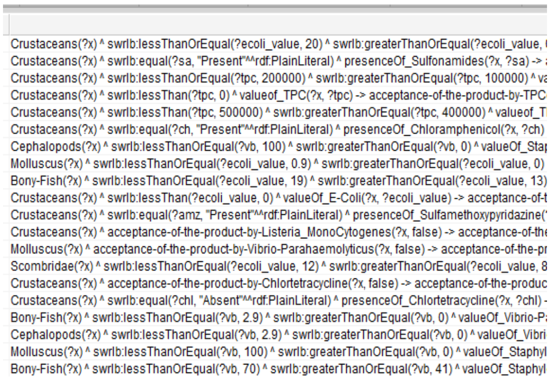

Figure 3. SWRL rules defined in SWRLTab

Results and Discussion

Here we will demonstrate two instances of Crustaceans samples, Crabs1, and Crabs2. Fig. 4 displays the data property assertions of Crabs1, an instance of Crustaceans.

Data properties are used to store the results of different tests of the seafood. For example, data properties such as presence Of_Sulfonamides, presenceOf_Nitrofurans, value Of_Staphylococcus_Aureus etc. are used to represent the test result values.

Under each category of Fish, there are subclasses such as Accepted and Not_Accepted. When the Pellet Reasoner starts reasoning, each instance of the fish sample will be automatically categorized into one of these classes depending on the output generated.

Here for Crabs1 instance, all the test results are satisfied as stated in Rule 1, so the instance is categorized under Accepted_crab class (Fig. 5). The new facts related to Crabs1 instance inferred by the Pellet reasoner is shown in Fig. 6. For example, acceptance-of-the-product-by-Nitrofurans resulted in true as the presenceOf_Nitrofurans was asserted as 'Absent' for Crabs1 instance according to Fig. 4.

Figure 4. Data property assertions of Crabs1, an instance of crustaceans

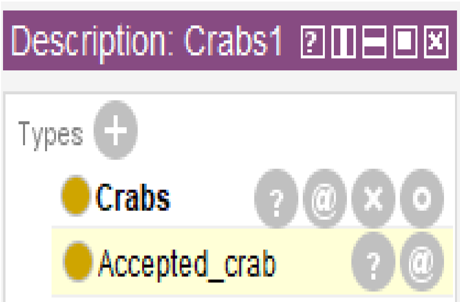

Figure 5. Automatic classification of Crabs1 instance under Accepted_crab class

Similarly, Crabs2 instance produce an output as "NOT ACCEPTED" and get categorized under the sub class Not_Accepted_crab (Fig. 7). This may occur if any of the test results done for Crabs2 fails to be true. Fig. 8 shows the inferred facts about the Crabs2 instance that were discovered through reasoning by the Pellet reasoner. From Fig. 8, most of the tests failed in the case of Crabs2 instance, resulting in the Not_Accepted category.

Conclusion

Seafood is one of the most widely consumed foods on the planet. As a result, seafood quality and safety are key concerns. By concentrating on fisheries and seafood exports, international trade can be improved, leading to increased development in the fisheries sector. The proposed Seafood ontology system is an automated system that determines if a specific category of fish is acceptable based on test specifications required in various countries. Ontologies define classes, subclasses, and relationships, all of which aid in meaningful information retrieval. Creating an ontology for a certain domain is a skill, and no two ontologies for the same domain defined by different persons can ever be identical.

The focus of this research paper is the modeling of HACCP test guidelines using SWRL. The ontology is reasoned using the Pellet Reasoner. The output obtained while applying the SWRL rules on the Crab category that comes under the class Crustaceans is demonstrated in the paper. Two different instances (samples) of Crustaceans are tested by asserting the test values. Concerned SWRL rules (HACCP guidelines) are applied, and the instances are correctly classified under the Accepted/Not_Accepted ontology classes. Lab technologists will be able to certify the quality of seafood for export under this approach. Currently, ontology research and development are gaining attraction all around the world. More information regarding seafood can be added in the future, as the ontology is refined for the next level.

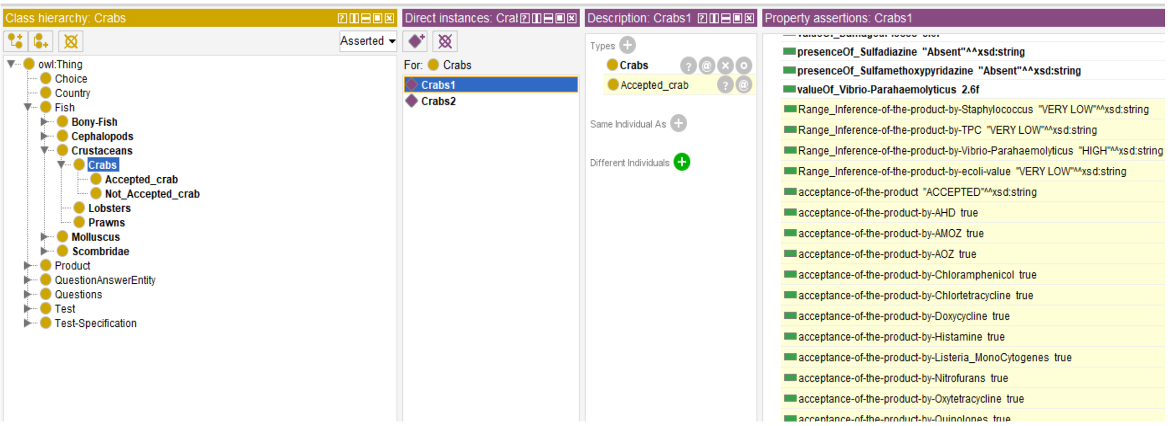

Figure 6. Inferred facts related to Crabs1 obtained through inference

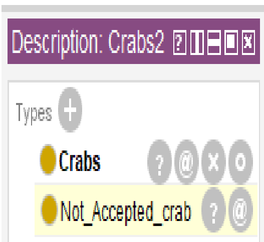

Figure 7. Automatic classification of Crabs2 instance under Not_Accepted_crab class

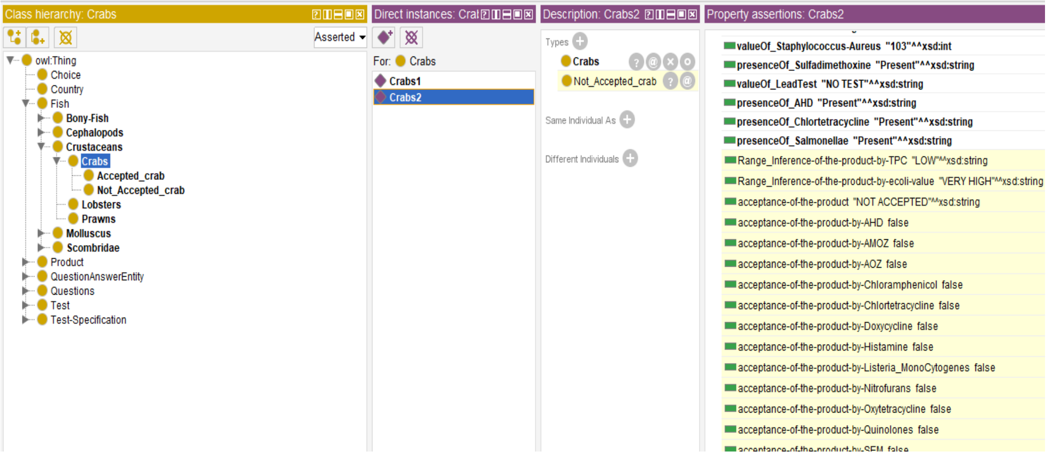

Fig. 8. Inferred facts related to Crabs2 obtained through inference

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