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A Safety Food Consumption Mobile System through Semantic Web Technology

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***Abstract*—Over 3,000 compounds are being added to processed food. These compounds have numerous effects on food: add color, stabilize, texturize, preserve, sweeten, thicken, add flavor, soften, emulsify, and so on. According to a recent report by the World Health Organization, governments have lately focused on legislation to reduce such ingredients or compounds in manufactured foods for they might have side effects causing health risks such as the heart disease, cancer, diabetes, allergens, obesity, etc. Safety in food consumption especially by patients of risk groups have become crucial for such health problems are in the top ten ranked health risks around the world. By supervising what and how much to eat as well as what not to eat, we can maximize a patient's life quality by avoiding unhealthy ingredients or compounds. In helping patients take control of their safe food consumption, we need smart personal e-health systems. Smart personal e-health systems with advanced knowledge management technology can provide suggestions of food appropriate for consumption by individuals. Accessing annotations in the ontology knowledgebase of food appropriate to their personal health condition can be provided. This article discusses one such software application, namely the Safety Food Consumption Mobile System, employing Semantic Web Technology.**

Keywords*— Food Ontology, Semantic Web, Semantic Search Systems, E-health systems, Semantic Matching.

I. INTRODUCTION

Food and drink have influence in health risks such as heart diseases, cancer, diabetes, allergens, obesity, etc. Safe food consumption, especially by patients of these risk groups has become crucial for these health problems are among the top ten ranked health risks around the world. By controlling what and how much to eat as well as what not to eat, we can maximize the patients' life quality, decrease usage of unhealthy ingredients or compounds such as oxidants, etc. To take under control of safe food consumption by patients, we need smart systems that have strong knowledge management technology and could be easily extended to provide information from additional e-health tools.

In addition, a new Web technology is Semantic Web [1] or Web 3.0 provides to create *Ontology* [2] which contains machine-readable (semantic) annotations of health risk groups, unhealthy ingredients or compounds in foods, appropriate food consuming according to risk groups, patients' properties and so on. Through the Semantic Web approach, the ontology usage and technically the personal health systems are based on ontology knowledge management, which is easily extensible to adopt by other additional e-health tools. The ontology is shared between personal health services and e-health tools that provide interoperation that is specified by using Web Ontology Language (OWL) [3].

This article discusses a Safety Food Consumption Mobile System (SFCMS) through Semantic Web technology that serves easy to carry out and understandable suggestions to a member consumer while searching for an appropriate packaged food product from market shelves according to his/her health intolerance information. The packaged food products on the market shelves are needed suggestion to the food consumers via smart suggestion systems according to consumer's food intolerance information.

According to the law, food firms have to report the details of their produced products such as ingredients, additives and other details to its country's agriculture ministry. Therefore, the database of the country's agriculture ministry keeps a unique International Article Number (EAN)[1] of each produced product via QR Codes or barcodes that are printed on the package of food products while producing stage. Thus, the suggested system investigates such type of the product details via QR code or barcode number and then parses concepts from the food ontology to perform suggestion functionalities. The system knows negative effected nutrients and food additives of the member consumer's health disease and then it matches those with involved nutrients and food additives of a selected product through a series of semantic based search operations via smart devices during the shopping foods from market shelves. In future, such healthy food consuming suggestion systems may consider appropriate food consuming plan for individuals by accessing to annotations of appropriate food consuming according to their personal health information through the food ontology knowledge bases [4-8]. The proposed system's mobile application will enable consumers to use an interface as a web service to perform Safety Food

[1]http://en.wikipedia.org/wiki/International_Article_Number_%28EAN%29

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Consumption Mobile System transactions online. The system uses its own ontology knowledgebase that involves three sub ontologies: Human, Disease and Food Ontology knowledge bases. Following sections mention them, implementation of the system, a case study and conclusion. In the next section, a detailed description of the system's ontology knowledgebase, and then the working mechanism of the system are discussed.

II. Food Ontology Knowledgebase

The aim of Food Ontology is to represent an abstract model of different types of foods which contains foods' nutritional information including the types and amount of nutrients, additives/compounds information, energy information and the recommended daily intake. In other words, the ontology covers nutrients, food additives, and energy information of food products in a semantic way. In respect of a food product, the ontology is used by the proposed system in matching:
- the list of concepts (from disease ontology) for negative effected nutrients of a consumer's according to health disease type and,
- the list of concepts (from food ontology) for food additives/ nutrients.

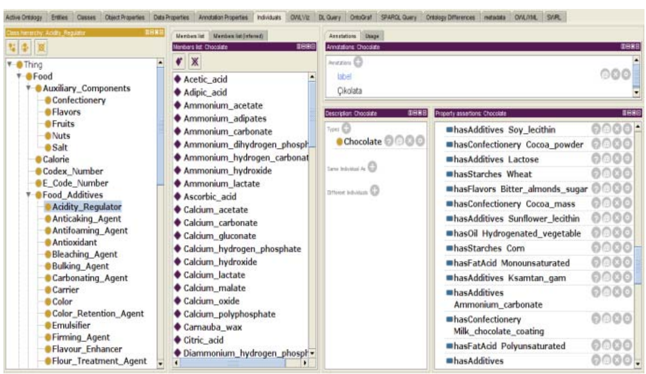

Fig. 1. A part of food ontology of the Mobile Healthy Food Consume Suggestion System.

Ontological structure of the Food Ontology () and its semantic rules are created in OWL 2.0 by using Protégé editor[2] [9] in the form of SWRL[3] (Semantic Web Rule Language) (Fig. 2). The semantic food contexts are described in the food ontology using OWL semantic tags such as *<owl:class>*, *<rdfs:subClassOf>*, *<owl:DatatypeProperty>*, and *<owl:ObjectProperty>*. Table 1 depicts a portion of the Food Ontology in the OWL 2.0 form that keeps almost 93 compound and 392 food additive concepts about the food domain such as "Acidity_Regulator", "Anticaking_Agent", "Auxiliary Components", "Codex Numbers", "Antioxidant, "Calorie" or "Food_Additives" etc. The "Food_Additives" contains also various subclasses "Anticaking_Agent", "Antifoaming_Agent", "Antioxidant" etc. The ontology also contains properties such as "hasAdditives", "hasAminoAcid", "hasCalorie", "hasSynonym" and etc. of the domain.

TABLE I. A Small Portion of Food Ontology in OWL

```
<Ontology xmlns="http://www.w3.org/2002/07/owl#"
xml:base="http://www.semanticweb.org/ontologies/FoodKB">
 <Declaration>
  <Class IRI="#Acidity_Regulator"/>
  <Class IRI="#Anticaking_Agent"/>
  <Class IRI="#Antioxidant"/>
  <Class IRI="#Calorie"/>
  <Class IRI="#Carbohydrates"/>
  <ObjectProperty IRI="#hasAdditives"/>
  <ObjectProperty IRI="#hasAminoAcid"/>
  <ObjectProperty IRI="#hasCalorie"/>
 </Declaration>
 <SubClassOf>
  <Class IRI="#Acidity_Regulator"/>
  <Class IRI="#Food_Additives"/>
 </SubClassOf>
 <SubClassOf>
  <Class IRI="#Anticaking_Agent"/>
  <Class IRI="#Food_Additives"/>
 </SubClassOf>
 <SubClassOf>
  <Class IRI="#Antifoaming_Agent"/>
  <Class IRI="#Food_Additives"/>
 </SubClassOf>
 <SubClassOf>
  <Class IRI="#Antioxidant"/>
  <Class IRI="#Food_Additives"/>
 </SubClassOf>
 <SubClassOf>
  <Class IRI="#Bleaching_Agent"/>
  <Class IRI="#Food_Additives"/>
 </SubClassOf>
 <SubClassOf>
  <Class IRI="#Chocolate"/>
  <ObjectSomeValuesFrom>
   <ObjectProperty IRI="#hasAdditives"/>
   <Class IRI="#Acidity_Regulator"/>
  </ObjectSomeValuesFrom>
 </SubClassOf>
 <SubClassOf>
  <Class IRI="#Chocolate"/>
  <ObjectSomeValuesFrom>
   <ObjectProperty IRI="#hasAdditives"/>
   <Class IRI="#Emulsifier"/>
  </ObjectSomeValuesFrom>
 </SubClassOf>
</Ontology>
```

III. Utilization in SFCMS

A. System Mechanism

The Safety Food Consumption Mobile System is an ontology-based software application that is designed based on semantic search, match and inference techniques. User interfaces as well being driven for ease of use, are catering to user needs and for use anywhere/anytime. The system application will enable customers to use an interface as a web service to perform its transactions online. The system application provides authentication to a member consumer who can query to get appropriate food consuming

[2] http://protege.stanford.edu/download/registered.html#p4.1
[3] http://www.w3.org/Submission/SWRL/

suggestions of the queried food product on the market shelves. The consumers get a report of these queried products that gives the information of nutrients and food additive details such as involved fat details and percentage measurements of ingredients.

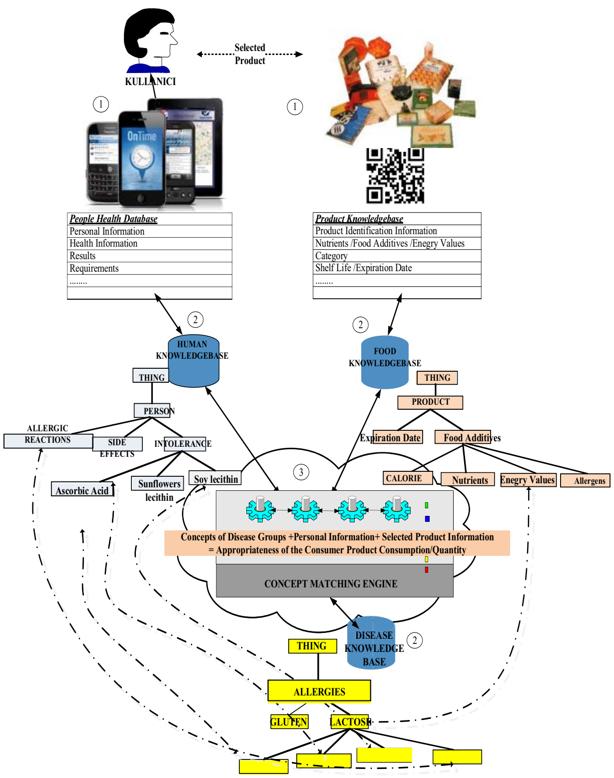

Fig. 2. System working mechanism through the Concept Matching Engine

Firstly, the system gets the nutritional information of a selected product according to its EAN number from product database. Then, the system starts to search its ontology knowledgebase and tries to retrieve the indicated concepts of the terms of nutritional information for the selected product. In addition to retrieving the nutritional concepts of commercial products from ontology, the system compares them with the specific nutritional concepts that have negative effects for consumer health. In order to perform this comparison, the system needs to reason with the concepts and relationships defined in three foundation ontologies, namely the Human, Disease and Food Ontologies. The food ontology knowledgebase is introduced above. Human and Disease Ontologies are of similar content. The comparison process of retrieved concepts from these ontologies is performed by *Concept Matching Engine* of the system (Fig. 1).

B. *Case Study*

People still consume food products without knowing what goes in it when they purchased from market shelves. The aim of this study is to find out and match food additives in food packs in order to observe sensitivity of buyers. Therefore, this section discusses a case study of a consumer striving to select food safe for the consumer's own consumption while shopping food products on shelves of a big market. For this purpose, this consumer uses the proposed system's mobile application. The customer could also use the system via kiosks (in the big markets), or any smart device such as phones, iPad etc. After login task, the system will require to scan the QR code of a food product that is tagged on the product pack. The QR code contains an EAN number of the food product. Then, the system will get the entire nutrient information, food additives and energy details of the scanned product via its EAN number from the food database. Querying to the database, the system connects the food search Web services of the Republic of Turkey Ministry of Food Agriculture and Livestock[4]. The system starts to search sensitive food additives and energy details according to the consumer disease (food allergy, heart disease, hypertension, cholesterol so on.) After that, the system will return the result of the suitability of the product for the customer food nutrients sensitivity.

The following scenario discusses a customer choosing two food products and then the system starts to evaluate their details in connection to the customer's health disease (for instance high cholesterol).

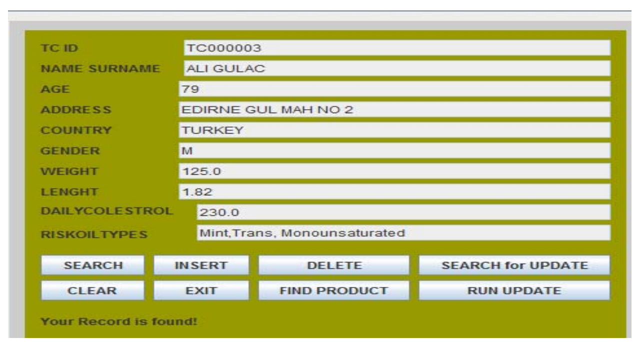

Fig. 3. A customer member log-in his account and choose a product category.

In our scenario, Mr. Gulac, who has high cholesterol, logs into the application system, while he is shopping in a supermarket. He has a smart phone that is able to connect to the Safety Food Consumption Mobile System application. He connects to the system via his citizenship number and password (Fig. 3). He wants to check a product on the market shelves in order to buy the suitable ingredients for his health disease such as allergy, heart disease or high cholesterol, etc. He then chooses a packaged food product from a shelf (For instance, first chosen product is *Ulker chocolate* product in Fig. 4 and then second chosen product is *Biscolata biscuit* product- Fig 6). He wants to be sure that the chosen product will not cause any side effect to his condition since his intolerances for risk type of oils: Mint,

[4] http://www.tarim.gov.tr/Sayfalar/Eng-1033/Anasayfa.aspx#

Trans, and Monounsaturated etc. He scans the QR code or bar code of the product on his mobile phone (or, alternatively through a market kiosk) and then the system retrieves all the nutritional information related to that product from database of the Ministry through its search product web services. Then, the system searches the nutritional information to get the indicated concepts in the food ontology. In addition to retrieving the nutritional concepts of commercial products, the system is able to compare them with the specific nutritional concepts affecting his health (see the warning messages on screens in the Fig 5 and Fig 7). The system presents three different colors as a result to the consumer: red, green and yellow. The mean of the Green light indicates *'the product is safe'* for the consumer (Fig 6 & 7) whilst *'red light is objectionable food product'* (Fig 4 & 5). In addition, the yellow light indicates possible issue, so the consumer should take professional medical advice before consuming that product.

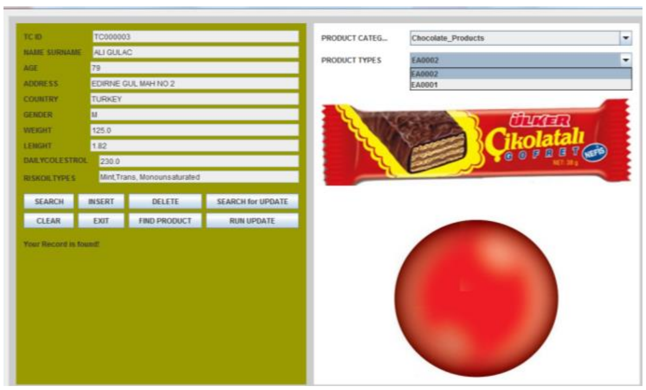

Fig. 4. The customer member chooses a product and gets the risky product sign (Result is Red).

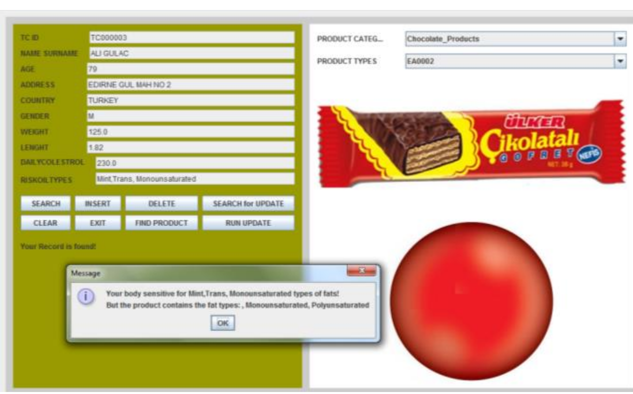

Fig. 5. The system shows the result message to explain reason for the risky product (The system explains why the result is Red).

In addition to above mentioned contributions of the ontology knowledge bases, such semantic declarations also used to infer meaningful and relevant information from the pre-asserted data on food products. That is done through an inference mechanism which is able to give an opportunity to discover an appropriate suggestion of a food consumption query for a specific health disease of a consumer. The Pellet [9] Reasoner supports reasoning with SWRL rules. Pellet interprets SWRL using the DL-Safe Rules notion which means rules will be applied only to the named individuals in the ontology. The SWRL rules are applied to infer the colored results to understand appropriate food product for individuals (consumer). However, the issue is out of the scope in this article.

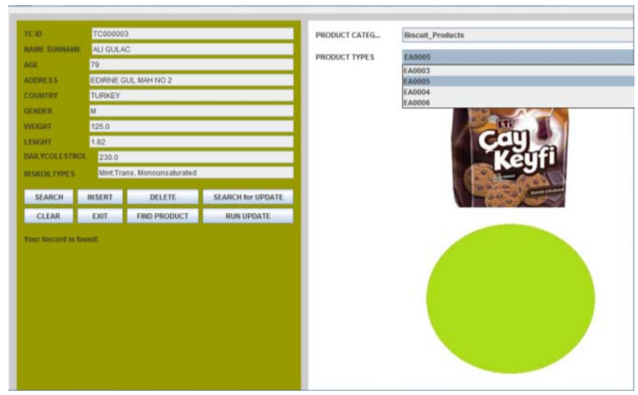

Fig. 6. The customer member chooses another product and gets the suitable product light (Result is Green).

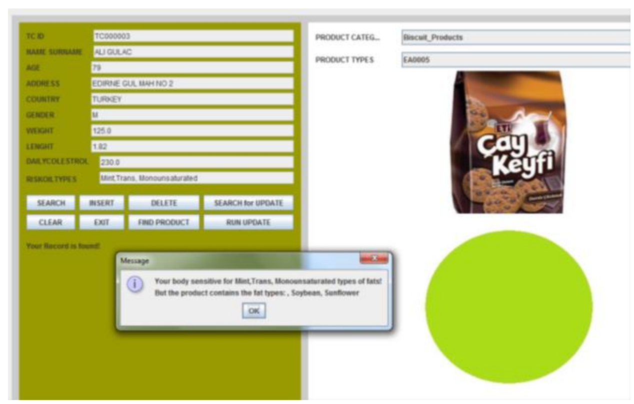

Fig. 7. The system shows the result message to explain reason for the suitable product for the customer (The system explains why the result is Green).

C. Semantic Matching

The Concept Matching Engine (Fig. 1) performs a semantic matching task that matches:

-the concepts of food ingredients of a selected product and,

-the concepts of side effected food nutrients of a consumer's health problem.

In order to perform this matching task, the system needs to perform certain reasoning using the concepts and relationships defined in three ontologies, namely the Human Ontology, the Disease Ontology and the Food Ontology. Assume that the concept of side affected food nutrients of a consumer's health problem is "Ascorbic Acid" appears in the Food Ontology. Then, the proposed search mechanism starts to find related concepts, properties, individuals, or synonyms of the user query term "Ascorbic Acid". Assume that, the system specifies the term "Ascorbic Acid" has two synonyms "Vitamin-C" or its E-codex standard name "E300-321", and has an is_a relation "Food Additive". The meaning of this: the "Ascorbic Acid" is a "Food Additive" and also an "Antioxidant" that has two synonyms "Vitamin-C" and "E300-321". In addition, if the consumer chooses a packed product on a market shelf during shopping: assume that it involves E-codex standard name "E300-321", then, the Concept Matching Engine of the system will recognize this synonym similarity since the food ingredients of the selected product has side effects for "Ascorbic Acid" that is not healthy nutrient for that consumer. Consequently, these concepts can be retrieved from domain ontologies, then send them to the system to enhance the lists of concepts:

-**Selected Product list**: concepts of the nutrients, food additives, food compounds etc. of the selected food product, and

-**Consumer Intolerance list**: concepts of the nutrients, food additives, food compounds etc. of consumer who has intolerances to them according to his/her health disease.

The advantage of semantic based search is that the search area is understood by machines. It gives an idea about "What am I looking for?" The possible answer is "I am looking about Ascorbic Acid" so, when searching an ontology knowledgebase for "What is an Ascorbic Acid?" it defines it as "Ascorbic Acid is a Food Additive and also an Antioxidant". A semantic search algorithm can distinguish the search areas or domains by using ontologies. If we use only syntactic-based search mechanisms in such systems, then we may have random and unhealthy nutrition.

D. Tools Employed

As the ontology knowledge bases of Safety Food Consumption Mobile System are semantic-based with OWL used in creating domain ontologies of the field, it eases semantic search and inference. In developing the ontology, the Protégé 4.1 [9] with OWL 2.0 support is the preferred tool. Java[5] programing language is used in the functional architecture of the system; inference over the ontology knowledge bases is through OWL API ver3.4.10 (2014-01-18) (Java based Ontology Parser) [10]. Important algorithms of the methodology base of the system are as follows:

- Jaro-Winkler distance [11]
- *'Semantic Matchmaking'* algorithm [12-14]
- Natural Language Processing (NLP) approaches[6], and
- Regular-expressions[7].

Based on these methods, the concepts of consumer's sensitive food nutrients information is matched with the concepts of the scanned or queried food product through human, disease and food ontologies (semantic matching) and then the returned result is served as hint for consuming decision by the consumer. It identifies the side effects to consumer as a report of the appropriateness before consuming decision. The semantic matching approach is similar to that of some recent studies of semantic service search in accordance with the users' needs [12-14].

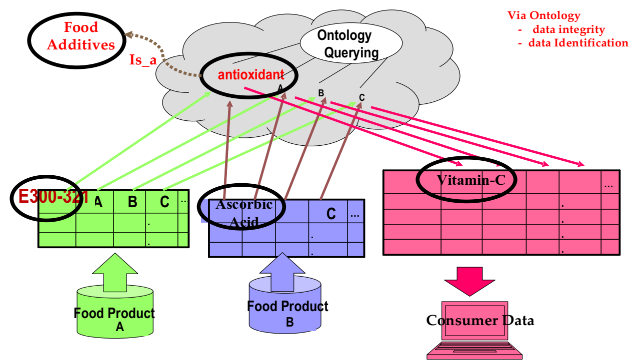

Fig. 8. Semantic Matchmaking through Ontology.

E. Concept Matching Engine (CME)

The inputs to the CME are the **Selected Product list**, *P*, and the **Consumer Intolerance list**, *C*. The output is a set of matched nutrients sorted according to similarity score. The CME focuses on these two lists of the nutrient and food additive concepts, which are symbolized as *P* and *C* above. The CME uses the matching scores of the concepts of these two lists, where Dissimilar=0, Subsume=0.5, Plugin=0.75, and Exact=1. The four degrees of similarity are related as follows: Dissimilar<Subsume<Plugin<Exact.

P: The set of input concepts of the **Selected Product list**,
C: The set of input concepts of the **Consumer Intolerance list**,
D: The set of all concepts/classes defined in the food domain ontology, the diesase ontology, and human ontology.

Exact Relation: A 1-1 mapping $P \to C$ where $\forall x_{Pi} \in P$ *and* $\exists x_{Ci} \in C$ such that $Concepts(x_{Pi}) \equiv Concepts(x_{Ci})$: any two focused concepts (P_i and C_i) of both list with the same or equivalent concepts or having a hasSyn() relation.
• For instance, if (P_i="Ascorbic Acid" and C_i="E300-321") or (P_i ="E300-321" and C_i ="Vitamin-C") or (P_i ="Vitamin-C" and C_i ="E300-321") then an exact relation exists, giving a score of 1.
Plugin Relation: A 1-1 mapping from $P \to C$ where $\forall x_{Pi} \in P$ *and* $\exists x_{Ci} \in C$ such that $Concepts(x_{Pi}) \subset Concepts(x_{Ci})$: if any focused concept (P_i) of the *product nutrients, P,* is a subset or subclass of the concept of *consumer intolerance nutrients C*'s input (C_i), or has a hasSyn() or hasIs_a() property, then a Plugin relationship exists.
• For instance, if (P_i="Vitamin-C" and C_i="Antioxidant") or (P_i="E300-321" and C_i="Antioxidant") or (P_i="Ascorbic

[5] http://java.sun.com/products/archive/j2se/6u7/index.html
[6] http://en.wikipedia.org/wiki/Natural_language_processing
[7] http://en.wikipedia.org/wiki/Regular_expression

Acid" and C_i="Antioxidant") etc., then a plugin relation exists, giving a score of 0.75.

Subsume Relation: A 1-1 mapping from $P \rightarrow C$ where $\forall x_{Pi} \in P$ *and* $\exists x_{Ci} \in C$ such that $Concepts(x_{Pi}) \supset Concepts(x_{Ci})$: if any focused concept (P_i) of the *product nutrients, P,* is a superclass of the concept of *consumer intolerance nutrients C*'s input (C_i), or has a hasSyn() or hasIs_a() property, then a Plugin relationship exists.

• For instance, if (P_i="Antioxidant" and C_i="Vitamin-C") or (P_i="Antioxidant" and C_i="E300-321") or (P_i="Antioxidant" and C_i="Ascorbic Acid") etc., then a subsume relation exists, with a score of 0.5.

Dissimilar Relation: A 1-1 mapping from $P \rightarrow C$ where $\forall x_{Pi} \in P$ *and* $\exists x_{Ci} \in C$ and $Concepts(x_{Pi}) \neq Concepts(x_{Ci})$: if there is no relation between the inputs of the two lists, a dissimilar relationship exists.

• If (P_i="Vitamin-C" and C_i="Glucose") then a dissimilar relation exists, which is scored as 0.

Clearly the following relations hold among the concepts of these lists $P \subseteq D, C \subseteq D$. The similarity score is computed using the Algorithm 1.

Algorithm 1 degreeOfProcessMatching (Concept P_i, Concept C_i)

1 **if** (($P_i \equiv C_i$) **or** (hasSyn(P_i)$\equiv C_i$) **or** ($P_i \equiv$hasSyn(C_i))) **then** return rel=**EXACT**;

2 **if** (($P_i \subset C_i$) **or** (hasSyn(P_i)$\subset C_i$) **or** ($P_i \subset$hasSyn(C_i)) **or** (hasIs_a(P_i)$\equiv C_i$)) **then** return rel=**PLUGIN**;

3 **if** (($P_i \supset C_i$) **or** (hasSyn(P_i)$\supset C_i$) **or** ($P_i \supset$hasSyn(C_i)) **or** ($P_i \equiv$hasIs_a(C_i))) **then** return rel=**SUBSUME**;

4 **if** (($P_i \not\equiv C_i$) **or** (hasSyn(P_i)$\neq C_i$) **or** ($P_i \not\equiv$hasSyn(C_i))) **then** return rel=**DISSIMILAR**;

IV. CONCLUSION

This paper describes a Safety Food Consumption Mobile System through Semantic Web technology especially for examining the packaged food products on market shelves that suggests the selected products' appropriateness to their consumers according to their health intolerances. The system contains its own ontology knowledgebase that involves three sub ontologies: Human, Disease and Food Ontology knowledge bases. The Food Ontology involves the nutritional information of commercial products and health care perspective. This system ontology knowledge bases are used to share knowledge between mobile smart devices of the food consumers in markets and product database of the Republic of Turkey Ministry of Food, Agriculture and Livestock via product search Web services. The problem we addressed with the design of the food consumption suggestion system is the provision of nutritional advice to market consumers according to their food intolerances or health diseases. The article describes briefly the design steps, working mechanism and use case of the proposed Safety Food Consumption Mobile System though semantic matching.

ACKNOWLEDGMENT

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[8] http://www.tubitak.gov.tr/en

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[10] http://www.acibademinternational.com/