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Nutrition for Elder Care: a nutritional semantic recommender system for the elderly

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Abstract: *The awareness and familiarity of elderly people with the use of new technologies have increased considerably in the last few years, which consequently cause a higher willingness to the use of these technologies in their daily lives. This allows the elderly to benefit from technology through active and conscious participation in activities related to health, leisure and promotion of social relationships, fostering active ageing. Three large dimensions cover almost a major part of health care within the framework of early and intermediate stages of active ageing: physical exercise, healthy nutrition and cognitive stimulation. In this paper, we present a nutritional recommender system, Nutrition for Elder Care, intended to help elderly users to draw up their own healthy diet plans following the nutritional experts guidelines. The system has been developed with the intensive use of Semantic Web technologies pursuing knowledge sharing and reuse between different applications and agents and the discovering of implicit new knowledge.*

Keywords: medical informatics, knowledge acquisition, knowledge representation, recommender systems, ontology reasoning

1. Introduction

Continued physical activity and good nutritional status are important determinants of physical and cognitive function in the elderly (Rosenberg & Miller, 1992). Several changes in body composition associated with ageing, as lean body mass loss caused by the wastage of muscle mass and increase of body fat, intensify the negative consequences of malnutrition in the elderly (Evans & Cyr-Campbell, 1997). This is particularly important because various studies demonstrate that many of the elderly do not feed well. This fact may be due to somatic, psychic or social problems such as decreased sense of taste or appetite, cardiac insufficiency, chewing or swallowing disorders, depression, social deprivation and loneliness (Pirlich & Lochs, 2001).

To prevent and even address these ageing-related problems, experts work on healthy nutritional and physical activity plans for the elderly along with cognitive stimulation programmes. Dietary assessment and recommendations comprise an important and effective aspect of preventing and treating a variety of morbid conditions in the elderly (Wells & Dumbrell, 2006). New technologies have much to contribute in this task. The elderly are becoming increasingly familiar and willing with technology. However, when attempting to consult online nutritional information in order to find suitable and healthy nutritional tips, they may find it difficult not only to assess how reliable, complete or sound such information sources are but also to handle all the information found. Recommender systems provide a way to help users in those tasks, storing the information provided by experts and offering it in the form of recommendations. However, traditional recommender systems suffer from some limitations, where one of the most important is the heterogeneity of information representation, preventing the communication and sharing between different agents, processes and systems. To alleviate this problem, some proposals have adopted Semantic Web technologies in the system development (Cantador *et al.*, 2011; Lops *et al.*, 2011; Szomszor *et al.*, 2007; Noguera *et al.*, 2006). Ontologies are one of the main technologies of the Semantic Web technology stack. They provide universal semantics, easing knowledge sharing and its unambiguous interpretation. They can be represented by means of the OWL Web Ontology Language (OWL 2 Web Ontology Language Document Overview, 2009), a Semantic Web formal and declarative language based on description logics (Baader *et al.*, 2005).

In the nutritional context, several recommender systems have been proposed. The first systems focused on obtaining appetizing recipes (Sobecki *et al.*, 2006), and more effort is lately dedicated to add healthcare requirements (Snae & Bruckner, 2008; van Pinxteren *et al.*, 2011). Systems targeted at users belonging to a more sensitive scope of the population, with stronger nutritional requirements, are starting to take an important role, especially in assisted living environments (Aberg, 2006; Lee *et al.*, 2008).

In this paper, we present a nutritional recommender system, Nutrition for Elder Care (NutElCare), which allows the elderly to create their own healthy diet plans according to their needs due to ageing. Although recommendations are always nutrient guided, it considers not only the healthy requirements but also the user taste preferences, hence contributing to a better motivation on the use of the system. The system identifies the nutritional requirements of users and assists them to benefit from the recommendations, following their daily and weekly healthy nutritional needs. It keeps track of the food ingested previously during the week in order to identify further weekly requirements, infer taste preferences when selecting among the set of recommendations and detect possible deficiencies with the help of monitoring support. In NutElCare, the knowledge from expert sources is represented through Semantic Web technologies. We introduce here the architecture of the system, illustrating how the use of these technologies contributes to alleviate the heterogeneity problems of traditional recommender systems, allowing, in addition, to share knowledge between different semantic processes or applications. Another goal in this paper is to demonstrate that the use of a declarative approach, that is, modelling the nutritional information by means of OWL ontologies, allows the inference of new knowledge that could not be extracted from traditional databases.

The remainder of this paper is organized as follows. Section 2 introduces some work related to active ageing support and nutritional recommender systems. In Section 3, the architecture and main components of NutElCare are explained. Finally, Section 4 presents our conclusions and future work.

2. Related work

Many research efforts in the field of technology devoted to elder care are focused on assisted living. Most of them are based on passive assistance in which user participation is not required and the work rests mainly on technology, as sensor networks (Fernandez-Luque *et al.,* 2014) or robotics (Spenko *et al.,* 2006). Talking about ageing assistance, in which the elderly are actively involved, the major part of research relies on usability of devices and interfaces. The lack of tools that help the elderly to actively deal with age effects concerning different aspects that promote self-sufficiency is substantial.

In addition, we found a considerable lack of systems intended to help elderly users in the nutritional dimension of health care. Next, we analyse some of the proposals found, focusing on the food recommendation, user nutritional profile, the management of the users' preferences and the monitoring of the users' nutritional state. One proposal found is FoodManager (Iglesias *et al.,* 2010), an assistive system that supports the elderly in eating and cooking activities. One of its cornerstones is the food recommendation, which supports weekly menus based on user disease pathologies, health conditions and preferences. The users can replace one recipe by another one to fit their preferences. This recipe is chosen from a list obtained from the recipe database where the only restriction is that the recipe fits the initial user disease pathologies, health conditions and preferences, without considering the previous ingested food, or the nutrients of the alternatives offered. The users indicate their preferences choosing which food they like or dislike from a list of ingredients. The nutritional state of the user does not seem to be considered in the system operation, and there is not any type of monitoring of the user ingestions or changes in their nutritional state. Although the user interface is designed considering elderly restrictions and can be displayed through a personal computer, the system requires special domestic appliance and sensors to its operation, and its elevated cost causes it to be economically unviable for most of the elderly population. Another system worth mentioning is provided in Aberg (2006), where the author suggests an intelligent food planning system to avoid the risk of malnutrition experienced by this sector of the population. It considers different constraints in the meals of the diets, such as preparation time, difficulty and cost, dietary restrictions as allergies or contraindications, and nutritional values. The system allows the user to replace one recipe with another contained in a top 5 list. It makes use of collaborative filtering for predicting taste preferences of a recipe according to other users' rates on this recipe and a content-based approach to fit the user nutritional needs. However, the system does not identify the nutritional requirements, but they must first be manually entered by caregivers instead, such as required intervals of fat or cholesterol. The nutritional profile of the user does not cover any information about the nutritional status, and the system does not provide a way to detect deficiencies in the ingested food or changes in the nutritional state. Sivilai *et al.* (2012) extend and adjust the menu recommender system food-oriented ontology-driven system (Snae & Bruckner, 2008) to provide diet plans for the elderly in hospital environments. This proposal consists a recommender system where the user profile is based on a medical health record derived from the diagnosis of a doctor, containing also the nutritional status and which food is liked or disliked. These preferences are indicated explicitly by the user, and the recommended diet plan cannot be further personalized. The knowledge base contains the food and nutrition ontology modelled from the Personalized Information Platform for life and health Services food classification, and a set of rules is defined for inferring the recommended meals, from a meals database, for building a diet plan considering the user needs and preferences. Again, there is not any monitoring task included in the system, and previous ingestions are not taken into account.

From this study carried out in our research, we discovered a serious lack of systems capable of helping elderly users to build a diet plan considering together their nutritional requirements and tastes preferences, where those preferences were more flexible than only likes or dislikes, but being also inferred from the user behaviour in the system. The personalization of the diets obtained is also a crucial factor for adjusting the diets to the user preferences, motivating the users to use the system. Finally, a major drawback found in the analysed systems is the absence of a monitoring component that allows the detection and notification of changes in the nutritional state of the user or deficiencies in the ingestions, critical factors to consider in the elderly health status.

3. NutElCare

NutElCare is a recommender system that provides healthy diet plans for the elderly. It retrieves reliable and complete nutritional information from expert sources, either humans (e.g. nutritionists and gerontologists) or computerized (e.g. information systems, nutritional databases from World Health Organization and Spanish Society of Parenteral and Enteral Nutrition), and manages this information, providing it to the users in the form of recommendations.

In order to improve the information representation, the system makes use of Semantic Web technologies in its development, resulting in a so-called semantic recommender system. The representation of expert knowledge is carried out through OWL ontologies, which encourage knowledge sharing and reuse. Moreover, thanks to the correspondence with description logics, it allows the inference of new knowledge not explicitly introduced in the ontology, by means of computer programmes known as reasoners. The reasoner used is Pellet (Sirin *et al.,* 2007), one of the most popular semantic reasoners to exploit OWL ontologies.

Concerning the strategy for performing recommendations, it can be considered as a hybrid recommender system (Burke, 2007) because it carries out more than one recommendation techniques, specifically, knowledge-based and content-based techniques:

- Knowledge-based techniques, which use explicit knowledge about users and items to generate a recommendation, reasoning about what items meet the user's requirements. In NutElCare, a rule-based reasoning is used to obtain the diet that fits the nutritional requirements of the user profile. Here, the items are the diets, for example, *diet_1*.
- Content-based techniques, in which recommendations are generated from two sources: the features associated with items and the ratings that a user has given them. In our system, content-based recommendations are carried out by means of semantic similarity calculations between nutritional features of food and the user's previous selections or 'food rates'. Here, the items are food or meals, such as *tomato* or *spaghettiBolognaise*.

The first recommendation carried out by NutElCare is a knowledge-based recommendation in which a healthy diet is obtained to fit nutritional requirements identified through the ontological user profile, which contains the relevant knowledge about the users in the nutritional context. After that, the content-based recommendation starts in order to personalize the diet obtained, and allowing the users to make variations on this diet to fit their taste preferences, or availability of ingredients. The recommendations must be flexible and must take into account the user preferences, their allergenic contraindications and which food has been taken during the week, offering alternatives to the original diet plan based on these factors. These recommendations are always nutrient guided, providing alternative suggestions of similar conditions, to continue meeting the original healthy requirements of the diet. The system learns from the user selections to improve further recommendations with user-inferred preferences.

3.1. NutElCare architecture

The NutElCare architecture is based on the main elements of the semantic recommender systems, as follows:

- Knowledge base and items representation: the knowledge base is built through a nutritional ontology, and the items (i.e. diets and food) are represented as individuals in the ontology.
- User profiling and learning techniques of user interests: the user is modelled as an ontological user profile, and automatic inference techniques are performed for learning from the user behaviour.
- Obtaining and providing recommendations about items in the knowledge base through semantic similarity measures.

We can thus represent the architecture of the system as shown in Figure 1. In NutElCare, the user is represented by means of the *User Profile* ontology, which contains the information about the user needed to carry out the recommendations. Once the user logs into the system through the *User Interface*, the corresponding profile is instantiated and included in the knowledge base, which previously contained the *Nutritional Ontology*. This latter ontology is formed by a food and diets taxonomy enriched with nutritional properties and the alimentary aspects that are combined into the recommendation processes. Now, both ontologies are bound and are therefore able to support reasoning as a single one. At this moment, the *Diet Manager* calculates and retrieves the diet from the XML diets repository that most fit the user profile. This diet must be personalized so as to take into account user preferences together with individual requirements, so it is consequently sent to the *Recommender* component, which performs reasoning operations over the knowledge base in order to obtain recommendations of possible alternatives on the food contained in the diet. The output of the Recommender is the already tailored diet, which is sent to the User Interface where it is presented to the user in the form of the recommended weekly diet plan with the possible alternatives. When the user selects among these alternatives, a feedback is sent to the *Learning* component, which is in charge of analysing the user's behaviour to infer implicit user preferences through automated inference techniques. The result of this analysis is directed towards the User

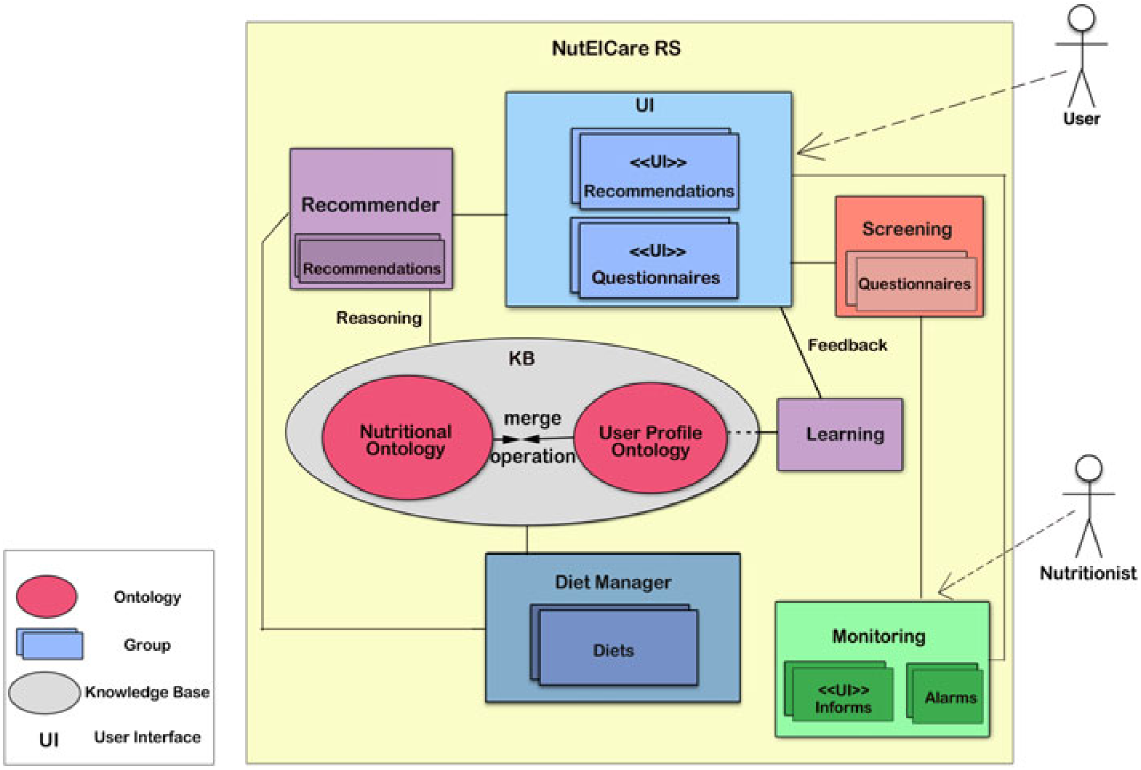

Figure 1: *Nutrition for Elder Care (NutElCare) components architecture.*

Profile ontology where it is stored, allowing in such way the inclusion of the learned preferences in further recommendation processes. The monitoring support is provided by both the *Screening* and *Monitoring* components. The former stores the questionnaires needed to evaluate the user's nutritional state at the different stages of use of the system and to know the dietary habits. The results are sent to the Monitoring component, which allows the caregivers to keep track of the user nutritional behaviour within the system, notifying users also through the User Interface when it detects some kind of worrisome fact, such as malnutrition risk or nutrient deficiencies. The next sections provide a more detailed explanation of each component.

3.2. User Interface

The system's success depends on it being enjoyable and easy to use while at the same time encouraging its correct and serious usage. As a consequence of both functional limitations and less technological experience, older users suffer more from usability problems than younger users (Ijsselsteijn *et al.,* 2007). For this reason, the user interface is designed taking special care of these particular usability requirements.

Although NutElCare can be used offline, its full potential is achieved online, because some components need to access and maintain data from different servers. Additionally, at this moment, the target devices in our project are personal computers or laptops. These facts have led us to the application of the guidelines, heuristics and best practices when designing user interfaces for the elderly in the context of browser-based applications, as specified in Becker (2004), Johnson and Kent (2007) and Kurniawan and Zaphiris (2005). The key elements considered in the design for achieving an enjoyable and usable interface are used in the VIRTRA-EL project, which have been already tested (Rute-Pérez *et al.,* 2014). They can be summarized as follows: application of general usability requirements for the elderly (such as avoid scrolling, customizable font size and easy-to-read font), avoiding frustration and boredom, providing guides and not interfering decoration elements and promoting motivation through positive feedback and rewards. A significant sample of the efforts in following these guidelines is the use of a pictographic system intended for people with special cognitive requirements caused by age or disability. These systems have the advantage of allowing communication from a very basic level, which adapts to people with low cognitive levels or in very early stages, to a level of communication that is very rich and advanced. The pictographic system chosen was ARASAAC,[1] widely used in the various territories of Spain. An example of the interface of a screening questionnaire using ARASAAC pictograms is displayed in Figure 2. Non-functional properties (such as adaptability, anticipatory interaction

[1]ARASAAC. Gobierno de Aragón, Portal Aragonés de la Comunicación Aumentativa y Alternativa. http://www.catedu.es/arasaac/

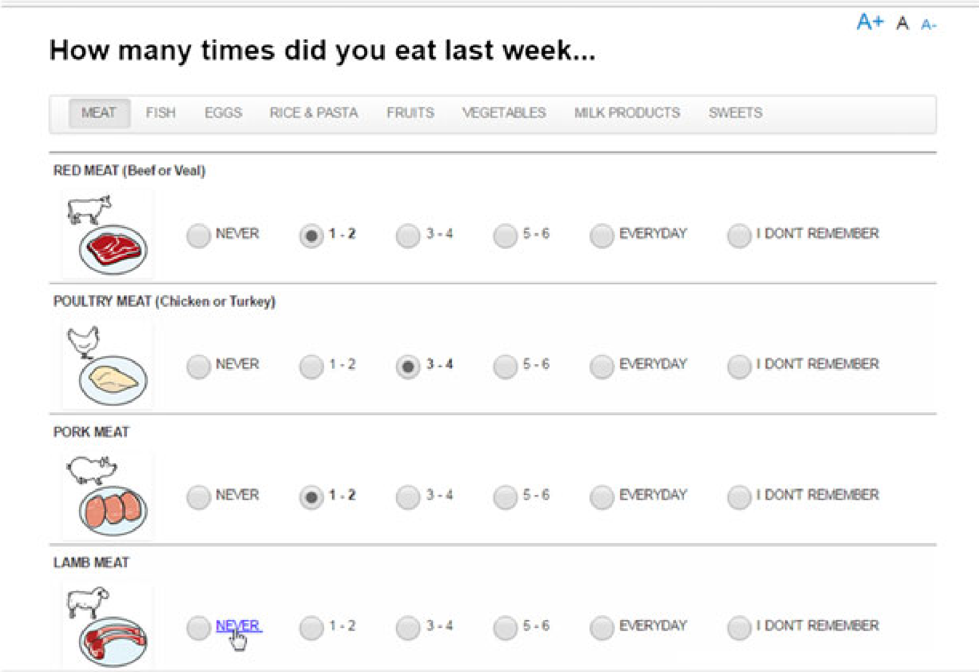

Figure 2: *Screenshot of Nutrition for Elder Care user interface using ARASAAC pictograms.*

and heterogeneity) of ambient home care systems have a major impact on the overall acceptance of the system, and additionally, ethical, social, medical and technological constraints are considered (Kleinberger *et al.,* 2007).

3.3. *Nutritional ontology*

The knowledge base of NutElCare is represented as an OWL ontology, to which the nutritional expert knowledge has been transferred. The ontology is mainly formed by a food taxonomy enriched with nutritional properties and the alimentary aspects that are combined into the recommendation process. For reusability, internationalization and institutionalization purposes, the nutritional ontology is built from the AGROVOC Food and Agriculture Organization thesaurus (Caracciolo *et al.,* 2013) of the United Nations. In order to fit the requirements of a nutritional recommender system, only the relevant information related to nutrition was extracted from the AGROVOC thesaurus, and nutritional properties of food were added to the ontology. Although AGROVOC covers more than 20 languages, only Spanish and English have been included. The concepts of the ontology are linked to the corresponding codes of AGROVOC, so that concepts in NutElCare can be mapped into terms in the AGROVOC thesaurus. The ontologies of this work have been edited using Protégé 4.1.[2] An excerpt of the nutritional ontology in Protégé is displayed in Figure 3.

The inclusion of nutritional properties in the ontology is crucial for the subsequent reasoning, and the semantic similarity calculations are involved in the recommendation processes. We have categorized the nutritional object properties, as follows:

- Level properties: classify the nutritional level of some nutritional property.
- Typical properties: the rest of the nutritional properties.

To clarify these properties, a sample of 'property assertions' of the *Cucumbers* instance is shown in Figure 3. In it, the property *isRichIn* is a typical property, and *Caloric Level* and *Protein Level* are level properties that classify the datatype properties *calories per 100 gr* and *proteins per 100 gr*, respectively. Beige shadowed assertions in the screenshot correspond to facts inferred by the Pellet reasoner and not explicitly expressed in the ontology. The figure also shows the mapping of this instance with its correspondent term in AGROVOC, through the property *Agrovoc Code*.

Once the user logs into the system, its instance of the user profile becomes also a part of the knowledge base through the OWL *merge* operation.

3.4. *User Profile ontology*

The information about users is modelled through ontological profiles. These profiles are composed of the explicit information, obtained in the user registration process, and the implicit information, dynamically built with the reasoner and the help of the learning component as it studies the behaviour of the user in the system. The ontology that represents the user model has been made as reusable as possible to be used in the nutritional recommendations domain with minor or no changes. It

[2]Protégé 4.1, Stanford Center for Biomedical Informatics Research, Stanford University. http://protege.stanford.edu

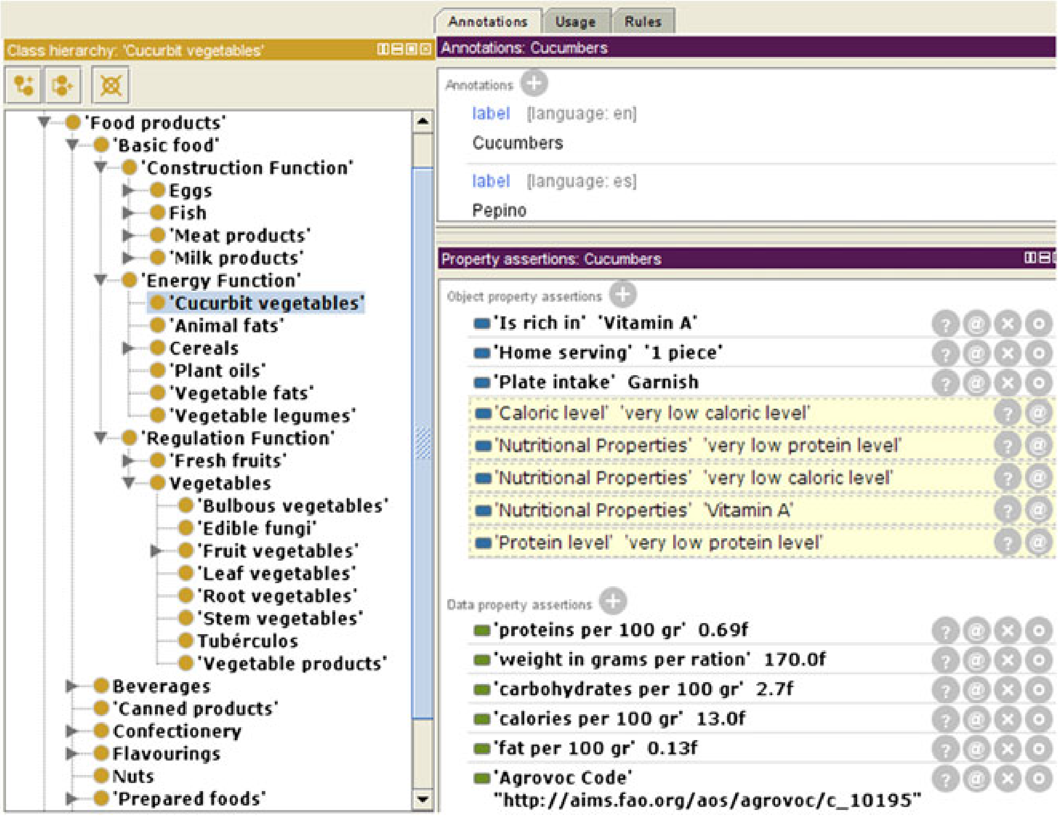

Figure 3: *Nutritional ontology excerpt and property assertions of the Cucumbers instance after reasoning with Pellet.*

has been developed by extending generic user model ontology (Heckmann *et al.,* 2005) with new properties and concepts related to the nutritional domain.

To produce a diet, in addition to typical *demographic data* (such as name, gender, age and address), the following information of the user is required. *Physical properties*: This contains the user's weight and height to calculate the body mass index. From it, NutElCare classifies the nutritional state of the users, as follows: malnourished, underweight, normal weight, overweight or obesity. Other properties to include are the swallowing and chewing ability, to distinguish whether the user needs normal, soft, semi-liquid or easily digested diets. *Environmental factors*: This contains the season and geographical area in which recommendations are made. *Activity factors* represent the amount of exercise that the user carries out in a week (active, standard or sedentary life). *Allergies, contraindications and dislikes* determine which food should be excluded from recommendations considering this food as 'no-interesting'. *Socio-economics, culture and religion*, as pointed out in Al-Nazer *et al.* (2014), are user properties that can be determinants to provide nutritional recommendations. For instance, some religions and cultures do not allow the ingestion of some kinds of food. *Previous ingestions and selections* are food that have been already ingested and in which selections of the recommended food have been made. This latter information will be used by the learning component in order to build and improve further recommendations.

3.5. Diet Manager

This is responsible for retrieving the suitable diet models for a user profile using knowledge-based techniques. One of these techniques are the semantic SWRL rules (Horrocks *et al.,* 2004), which are used to perform rule-based reasoning over elements of the ontology. Suppose that we want to state that adult and caloric diets are suitable for adult underweight persons, and then we include the following SWRL rule:

```
Adult(?p),'Adult diet'(?d), 'Caloric diet'(?d),
'has Nutritional State'(?p, underweight) ->
'Diet Suitable For'(?d, ?p)
```

Once a diet model is selected, it is sent to the Recommender to be tailored according to the user profile.

3.6. Recommender

When a diet is received from the Diet Manager, it must be personalized to fit the user requirements and preferences. First, the Recommender checks the *not-recommendable* meals, which are meals that contain food items considered as *disliked*, *contraindicated* or *ingested max times* by the user profile. As an example, let's suppose that a person, Mary, is celiac, so she suffers from gluten intolerance, and the diet retrieved contains *spaghettiBolognaise*. Then, an inconsistence is detected in the reasoning process, so this meal is inferred as *not-recommendable*, because it contains gluten. The explanation of this inconsistence returned by Protégé is displayed in Figure 4. The recommender must replace this meal by another one that fits the nutritional requirements of the user.

When a meal needs to be replaced, by recommender's or user's choice, the recommender initiates a content-based operation in order to calculate alternatives to that meal. These alternatives are considered as the recommendations, which are closely linked to the nutritional properties of food and are computed through semantic similarity techniques and recommendation strategies. The strategy to calculate semantic is based on the weighted arithmetic mean, commonly used in recommender systems and adapted to taxonomic representation of the items (Espín *et al.*, 2013). First, we defined the *distance* between two food instances *i* and *j* as the minimum path between them in the taxonomy, using the subsumption links (`is-a` links) in the domain ontology. It is calculated through equation (1):

$$distance\ (i,j) = \min\{ca(i,j)\} \tag{1}$$

where *ca* is the common ancestor that subsumes both instances.

The semantic similarity between two food instances `i` and `j` is defined as the weighted arithmetic mean between the similarities of their nutritional properties divided by the distance between them using equation (2):

$$sim\ (i,j) = \frac{\frac{1}{T}\ \sum_{k=1}^{N} sim_{tp_k}(i,j) + \frac{1}{T}\ \sum_{l=1}^{M} sim_{lp_l}(i,j)}{distance\ (i,j)} \tag{2}$$

where $T = N + M$ is the total number of compared properties and *tp* and *lp* are typical and level properties.

Once the semantic similarity between the target food and its adjacent food items has been obtained, a *top K* list with the *K* most similar items in order from highest to lowest similarity is extracted. This list is reordered with user preferences factorization and attached to the diet, which is sent to the User Interface.

3.7. Learning

This analyses the user behaviour in the system interaction. It uses automated inference techniques to extract behaviour patterns and communicates them to the user profile in order to build the dynamic part of the profile, which is composed of the implicit information collected. In particular, in each recommendation to a user, it manages a vector $\mathcal{V}_f$ with elements for each replaced food, where $\mathcal{V}_f = \{\mathcal{P}_1, \mathcal{P}_2, \ldots, \mathcal{P}_\mathcal{N}\}$ with $\mathcal{N}$ being the number of possible alternatives to offer for replacing $\mathtt{f}$, and $\mathcal{P}_i$ one of these food possible alternatives, where

$\mathcal{P}_i = (\mathfrak{f}_s, \mathfrak{f}_r)$ with:
i → position of $\mathcal{P}$ in the vector $\mathcal{V}_f$
$\mathfrak{f}_s$ → number of times selected as alternative of f.
$\mathfrak{f}_r$ → number of times recommended as alternative of f.

Next, a factor value, μ, is calculated for each alternative in the recommendation list with equation (3), and this list is rearranged on the basis of this factor.

$$\mu = \frac{\mathrm{fs}}{\mathrm{fr}\ i} \tag{3}$$

Let us suppose that the food item $\mathtt{f}$ to be replaced is *chicken-meat* and the recommendation given by the recommender is the list of possible alternatives, $\underline{\mathrm{R}}_{\text{chicken-meat}} = \{food_1, food_2, food_3, food_4, food_5\}$ and the vector $\mathrm{V}_{\text{chicken-meat}} = \{(1{,}3), (0{,}2), (3{,}5), (4{,}4), (1{,}2)\}$. Applying the factor μ to each alternative: $\mathrm{V}_\mu = \{0.33, 0, 0.2, 0.25, 0.1\}$ and sorting from highest to lowest: $\mathrm{V}_\mu = \{0.33, 0.25, 0.2, 0.1, 0\}$. Then, the final recommendation list is $\hat{\mathrm{R}}_{\text{chicken-meat}} = \{food_1, food_3, food_4, food_5, food_2\}$.

3.8. Screening

This component is responsible of the evaluation of the nutritional state of the user at the different stages of use of the system. The screening strategy used is the Mini Nutritional

Figure 4: *Inconsistence when spaghettiBolognaise is contained in a diet for a celiac person.*

Assessment (MNA; Guigoz *et al.,* 1997) in its short form (MNA-SF; Rubenstein *et al.,* 2001). MNA is considered the most widely used methodology for the brief evaluation of older persons' nutritional status (Delacorte *et al.,* 2004). MNA-SF is able to identify malnourished persons or persons at risk of malnutrition. It consists a short questionnaire that users fill in every 3 months (this value can change but is the recommended one by the MNA) via the user interface. The result of this questionnaire is determined by the scored points obtained from the user's answers in which 12–14 points indicate normal nutritional status, 8–11 points indicate malnutrition risk and 0–7 points mean that the user is malnourished. These results are sent to the monitoring component.

3.9. *Monitoring*

This component contains all the MNA results of the users and whether he or she has followed the daily recommendations or not, including, in this case, why these have not been followed and what has been ingested instead. In this way, the nutritionist and the system itself are aware of the impact that the use of the system causes to the user and the real daily food ingestion. It can be accessed by the nutritionist at any time for consulting a specific user or obtaining different information of the results. Essential elements of the monitoring component are the *Alarms*. When the monitoring detects nutrient deficiencies, possible symptoms of malnutrition or its risk in a specific user, it sends an alarm notification to the caregiver and the user itself via email and notifications. At this moment, the state of the system changes to *waiting* until it is notified to resume and continue with its normal operation.

4. Conclusions and future work

Nutrition is an important determinant of health in elderly people. Nutritional assessments and recommendations can prevent and even treat the adverse effects of ageing, contributing to elderly well-being. Recent awareness and familiarity of the elderly with new technologies encourages the development of tools that they can use for their own benefit. However, many of the current proposals providing ageing support are intended for telemonitoring purposes without intervention of the users. The lack of systems that the elderly can use by themselves to deal with age effects, particularly in the nutritional domain, has been one of the main motivations of this work.

In this paper, we have presented the architecture of NutElCare, a recommender system that provides healthy diet plans to the elderly following the expert guidelines. In order to motivate users to use the system and follow the nutritional assessments, the recommendations are adapted to the taste preferences of the users. With this strategy, the user benefits from healthy and appealing recommendations. Furthermore, usability and accessibility are satisfied through the application of best practices and guidelines designed for Web applications targeted at the elderly population.

We have exposed as well the broad architecture of the system, in which the nutritional knowledge from expert sources has been transferred. In order to overcome the heterogeneity problems of previous recommender systems, this knowledge have been represented using Semantic Web technologies, which has allowed us the reuse and sharing of external semantic information sources such as AGROVOC thesaurus or generic user model ontology user profiles. Another highlight of this work is the demonstration of how the integration of the OWL ontologies into the system architecture allows the inference of implicit new relevant knowledge to be used in the food recommendation process. In addition, this declarative approach boosts the inference of the same facts when the ontology changes; for instance, this system could be adapted to different sectors of the population by just readjusting the ontology.

Currently, NutElCare is being included into VIRTRA-EL (Rute-Pérez *et al.,* 2014), a platform that provides active ageing support. This integration aims to contribute to the holistic active ageing care supplying sustenance to three main dimensions associated to health and remarkably related to each other: cognitive stimulation, physical activity and nutrition.

An immediate future work is the analysis and experiment of different automated inference techniques able to enhance the effectiveness of the learned user preferences from the user behaviour in the recommendations. A formal evaluation of the results of the users' system interaction has also been prepared as part of the immediate future work. As further work, and taking advantage of the collaboration capability of VIRTRA-EL, we plan the addition of collaborative filtering and recipe sharing among users promoting the social aspects of active ageing.

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