Semantic Modeling for Personalized Dietary Recommendation

Andreas Arens-Volland, Benjamin Gateau, Yannick Naudet
IT for Innovative Services department
Luxembourg Institute of Science and Technology
L4362 Esch/Alzette, Luxembourg
Email: {*andreas.arens, benjamin.gateau, yannick.naudet*}@list.lu

***Abstract*—This paper presents an initial work concerning a holistic semantic modeling approach enabling personalized dietary recommendations. Focus is given here to the review of existing semantic resources and food information resources covering different aspects of the domain. A gap analysis in relation to a comprehensive conceptual model is given. This work is part of a recently started project named LiFANA - Lifelong Food and Nutrition Assistance (www.lifana.eu).**

I. Introduction

Personalized dietary advice aims at providing nutrition recommendations for achieving and maintaining individual's optimal health and disease prevention based on the individual lifestyle, anthropometric data, personal likes and dislikes, general preferences such as culture, taste, and budget, as well as medically based requirements, generally comprised in a *user model*.

A. Background

In general, *personalized nutrition recommendations* focus on macronutrients (carbohydrates, protein, fats, fiber), micronutrients (trace minerals like iron, chlorine, manganese etc., and vitamins), and bioactive substances comprised in food through assessing the nutritional appropriateness of *single food items*. However, the information about these substances is not always available on the nutritional fact labels on packed food products, right at hand for staple food, or difficult to assess in dishes, all of which makes it tedious for individuals to follow recommendations.

A further challenge is the evaluation of the appropriateness of the whole menu in respect of nutrient balance, calorie content, diversity, allergies, etc. This *meal planning* can also include communication with caregivers or relatives and support buying decisions. If performed manually, these steps require to look up the suggested daily allowances or recommended intakes, browse through recipes, adapting the required amounts of ingredients, taking notes such as shopping lists, browsing through advertisements in search for promoted items, and comparing products against each other in the supermarket. Grocery *shopping assistance* is able to help users planning their shopping by including the products necessary to prepare the meals contained in the meal plan. It aims to ease decision making between products by improving readability and conciseness of nutritional facts, and by providing personalized recommendations based on the user profile.

In practice, the nutrition recommendations are complemented with behavioral (change) advice [1] but in this paper we will focus on the pure dietary part.

Even though strategies that tackle nutrition exist, "a holistic approach to malnutrition and diet management that covers the entire life-cycle of a nutrition care process" [2] still lacks. Computer-supported dietary management technologies support the user and health care professional and various techniques are employed in different application areas, such as weight-loss, diabetes etc., as well as in scientific and commercial settings [3], [4]. To overcome the interoperability issues between the different system components and food-related data sources, open standards need to be adopted and refined.

The LiFANA project will focus on three types of service models (see Fig. 1):

1) meal and menu recommendations combined with shopping assistance for active seniors either based on pre-defined profiles or personalized by a nutritionist both approaches covering regional cultural profiles;
2) grocery delivery services for seniors who have difficulties to go to the supermarket; and
3) personalized tele-nutrition services from health professionals.

Although the LiFANA project focuses on elderly as a final target group, the depicted service models cover a wide range of involved stakeholders (nutritionists, retailers, formal and informal caregivers, etc.), addresses aspects of B2C as well B2B services, includes a variety of dietary restrictions based on different demands (health, culture, budget, etc.), and materializes the recommendation of items and meal planning into several concrete suggestions and support solutions.

Reliable ingredient lists and nutrition information about food have to be integrated with a meal recommender system (RS) and recipe databases. In this sense, LiFANA requires the integration of related yet unconnected knowledge models and food information resources (FIR). The most common FIR types are listed below.

- *Food composition databases (FCDB)* contain nutritional information of different food items, including macro and micronutrient information. Prominent examples include the US Department of Agriculture (USDA) FCDB or **CIQUAL** in France. The **EuroFIR** association[1] provides through its platform access to

[1] http://www.eurofir.org

978-1-5386-8225-8/18/$31.00 ©2018 IEEE

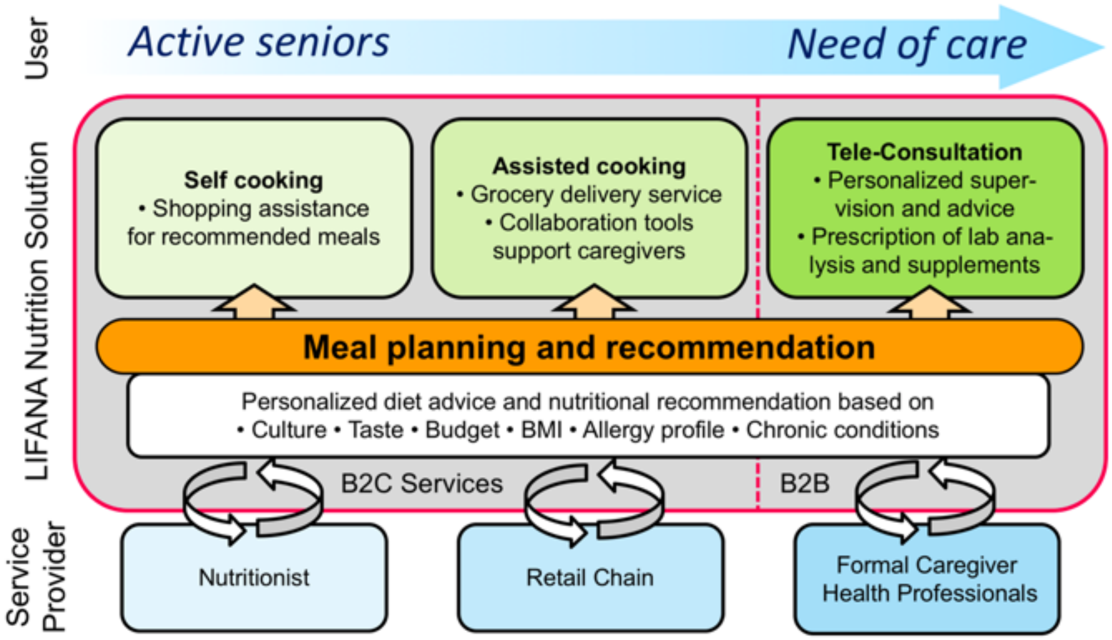

Fig. 1. LiFANA Service Models

harmonized food composition information for most European countries that where drawn from existing national databases.

- *Consumer packed goods (CPG) food databases* that provide information concerning consumer packed or branded food products. The EU directive "Food Information to consumers" EN 1169/2011, which forces online vendors to provide food-content information, is leading to new food information resources, e.g. **TrustBox**, to which the food manufactures directly provide the relevant information.
- *Recipe databases* are an essential information resource for providing meal planning and shopping assistance. Often the platforms allow to adjust the amount of ingredients needed to the intended number of portions to be cooked.
- Other FIR types exist such as *Sensory-Diet databases* [5] that can help to match the users' sensory preferences such as taste (sweet, sour, bitter, salt and unami) and preferred textures (hardness, mouth feel) with the properties of food items.

B. Related Work

Semantic modeling as well as semantic integration of information resources seem to be the most suitable approach, so we will review existing works on a) ontology driven dietary recommendation, b) recipe suggestion and menu planning, and c) mapping approaches for food information resources.

1) Ontology driven dietary recommendation: Several approaches for ontology driven dietary recommendation of food items exist. Espín and colleagues describe an elderly-focused nutritional RS following nutritional expert guidelines [6]. The knowledge base of **NutElCare** is an OWL ontology based on AGROVOC FAO thesaurus [7]. **SousChef** is a mobile RS capable of creating a personalized meal plan [8]. The SousChef RS takes anthropometric measures, personal preferences and activity levels of the users into account. An ontology-driven IoT-based food RS is presented in [9]. The **ProTrip** RS supports travellers with long-term diseases and followers of stric diet while considering climate attributes. Yusof et al. descibe a dietary menu RS suitable for diabetic patients [10]. The system employs a case-based approach exploiting a food ontology modeling the Malaysian FCDB. **DIETOS** is a RS for diet monitoring and personalized food suggestion to improve the quality of life of both healthy people and individuals affected by chronic diet-related diseases [11]. The ontology-driven mobile safe food consumption system **FoodWiki** [12] is designed based on semantic search, match, and inference techniques. The system enables customers to use an interface as a web service to perform online matching of intolerance and ingredient concepts. A survey of food RS in general is given in [13] and [14].

2) Recipe suggestion and menu planning: Freyne and Berkovsky describe a recipe recommender aimed at educating and sustaining user participation through food planning [15]. Individual recipe recommendations and meal plan recommendations are described in [16], [17], and [18]. The emergence of recipe and meal plan recommendation has also raised industry interest that can be referred to as *shoppable recipes*. In essence, the idea is to integrate one-click shopping into recipes creating the shop-by-recipe service alleviating the users of the burden to manually prepare shopping lists [2] as explained earlier.

3) Mapping approaches of food information resources: A general approach for mapping food and health research infrastructure is described by Bown and colleagues [19]. The

[2]thespoon.tech/amazon-teams-with-fexy-to-enable-food-shopping-within-digital-recipes/

authors provide examples of the types of food and health research facilities, resources and services available in Europe. In [20] several food ontologies are investigated and explored how the ontologies can be complemented with other relevant non-food ontologies. Despres describes a methodology adapted for a modularized ontology construction for the nutrition domain [21]. The proposed architecture covers concepts related to domains of food, kitchen, and persons.

While [19] focus on a description of existing resources from a research perspective, [20] targets mainly the automated identification of food and drinks supporting dietary assessment, and in [21] the cooking and sensory aspects are put into the spotlight.

This paper focuses on the combination of necessary information providing *personalized dietary recommendation*. It goes beyond the described literature above covering aspects of a holistic diet management and not only focusing on certain aspects or concepts in diet management. Further but related activities like dietary assessment and feedback channel (food intake, user rating, etc.) are not discussed here. The remainder of this paper is organized as follows. Section II briefly describes the approach and section III presents the existing resources for user modeling, food-related knowledge models, and other relevant tools. Section IV discusses the presented resources, and section V presents our preliminary conclusions and gives an outlook on future activities.

II. Methods and Implementation

An explorative search on existing ontological models in the broader food domain and diet management has been performed. For this, existing literature on food ontologies has been searched, reviewed, and the referenced citations followed. Scientific literature on ontology driven recommender systems has been explored to find out about underlying models. Also, ontology hubs like *Ontobee*[3], linked open data aggregators like *Linked Open Vocabularies*[4], and schema definitions[5] have been searched.

Existing standards and other relevant tools have been identified and evaluated. The resulting models have been analyzed based on their scope, granularity, and conceptualization paradigm. A coarse scope distinction includes the application domain and the extend of user modeling and/or food-related objects. A more fine-grained separation in the scope is depicted through the concepts and relations modeled. Lastly, the origin of a model and its intended use, like item recommendation, dish/recipe recommendation, menu recommendation, cooking assistance, and shopping assistance, play a major role in the design of an ontological model.

III. Results

A. User Modeling for the Personalized Dietary Recommendation Domain

Highly generalized user models include the so-called *Recommended Dietary Intakes* ***(RDI)*** or *Daily Recommended Allowance* ***(RDA)*** reference values of a specific set of nutrients, such as macronutrients or specific favorable vitamins. A prominent example is the *"Reference intake of an average adult (8 400 kJ/2 000 kcal)"* per day used in the labeling of food products. More specific user models are the nutrition recommendations for certain population subgroups expressed in guidelines by scientific associations, e.g. American Diabetes Association [22]. Individualized dietary recommendations are compiled by experts. The most specific and personalized models include the nutrition recommendations generated through genetic analysis, often referenced as *personalized nutrition* (in the same manner as personalized medicine) [23], [24]. Personalized nutrition represents a practical application of nutrigenetics and nutrigenomics. It aims at developing personalized nutrition recommendations for individual's optimal health and disease prevention based on individual's lifestyle, phenotypic and genetic profile. Personalized nutrition recommendations focus on the micronutrients and bioactive substances comprised in food.

The *Food Ontology Knowledge Base - FOKB* [12] describes persons through physical activity level, basal metabolic rate, blood pressure level, body mass index, and food hypersensitivity dietary restrictions.

B. Semantic Knowledge Models in the Food Domain

Food Product Ontology [25]: is a complement of a more global data structure description for e-commerce that is "industry neutral, i.e. suited for consumer electronics, cars, tickets, real estate, labor, services, or any other type of goods". The ontology adds new classes such as *Food* and *Ingredient* and its refinements into *Food additive* and *E-additive* as well as data properties such as *Carbohydrates Per 100g*, *Energy Per 100g*, *Fat Per 100g*, *Proteins Per 100g*, *Contains a GMO* and *Ingredients List*.

LIRMM Food (Product) Ontology [26]: models the food domain allowing to describe *recipes*, *food*, *food products*, *dishes*, and *ingredients* as well as data properties for nutrient content.

AGROVOC[6]*:* is a controlled vocabulary created and maintained by the Food and Agriculture Organization of the United Nations (FAO) containing more than 35,000 concepts available in 29 languages related to food, nutrition, agriculture, fisheries, forestry, environment etc. This thesaurus proposes a translation of terms in several languages. Concepts are defined in a scientific manner and the hierarchy is quite deep in order to reach simple concepts.

FOODS [27]: the food oriented ontology driven system comprises, among others, a food ontology and an expert system using the ontology, and some knowledge about cooking methods and prices. The ontology defines several categories of foods and food is categorized by nine main concepts: *regional cuisine*, *dishes*, *ingredients*, *availability*, *nutrients*, *nutrition based diseases*, *preparation methods*, *utensils*, and *price*. The goal of FOODS is to allow users to define some course regarding some requirements such as the ingredients, the type of cuisine, calories, vitamin and nutrients and some medical

[3]http://www.ontobee.org

[4]http://lov.okfn.org/

[5]http://schema.org

[6]http://aims.fao.org/vest-registry/vocabularies/agrovoc-multilingual-agricultural-thesaurus

constraints (disease). The challenge is then to populate their system with the right information.

Edamam company project[7]: Edamam's goal was to create a comprehensive food knowledge base becoming an authoritative source of cooking information. Edamam uses Ontotext Semantic Platform to map ingredients, cooking techniques, and tools to industry databases including the USDA's Standard Reference which provides a list of some 9000 ingredients, including full nutrition information over 140 nutrients. The Edamam food ontology includes *recipes*, *ingredients*, *nutrition information*, *measures*, *allergies*, and more. Based on the semantic facts stored in GraphDB, Edamam applied inferencing to derive more data including cooking time, dietary restrictions (e.g., Vegan, Vegetarian, Kosher, etc.), recipe classifications, recipe complexity, nutrition information per serving, and the degree to which the recipe contributes to a balanced diet.

Food Ontology Knowledge Base (FOKB) [12]: FoodWiki is an ontology-driven mobile safe food consumption system using semantic matching based on the Food Ontology Knowledge Base (FOKB). The system is especially designed for examining packaged food products on market shelves and suggesting the selected product's appropriateness to food consumers according to their health conditions or intolerances. The FOKB involves four main classes: *diseases*, *person*, *ingredients* and *product*. These classes contain many subclasses, properties, individuals and semantic rules. As a result, FOKB contains related concepts, properties, and annotations of food knowledge, such as food products, allergy conditions, person profiles, nutrients, food additives, and energy information, formatted in a semantic way. The semantic rules consider four types of risks through OWL object properties: *HAS_LACTOSE_RISK*, *HAS_GLUTEN_RISK*, *HAS_FISH_RISK*, and *HAS_EGG_RISK*.

FoodOn [28]: is an ontology built to interoperate with the OBO Library[8] and to represent entities which bear a food role. FoodOn imports material from several ontologies covering anatomy, taxonomy, geography and cultural heritage. The ALPHA version of FoodOn is largely based on LanguaL™(see section III-C). As FoodOn is striving to be OBO compatible, its classes (or facets as named in LanguaL™) are positioned within OBO's upper level ontology. FoodOn integrates **Eurocode2** food classification and EuroFIR food classification (for European Union) but also classifications for USA, international and other (cf. FoodOn ontology[9]).

Food Or Drink (FOD) ontology [29]: The application domain of this research is *cooking*. The final goal is to obtain a complete and detailed recipe in order to cook for a beginner or an elderly person with slight dementia. Indeed it includes everything from multi-lingual food taxonomies, restricted diets, nutrition impairments, meals, courses, dishes, flavor affinities to recipes and cooking. Instead on macro- and micronutrient content of the food, FoD focuses on flavor affinities. General concepts are reused from upper ontologies such as *DOLCE+DnS Ultralite ontology* (DUL) and *Quantities, Units, Dimensions and Data Types Ontologies* (QUDT) for standardized quantities and measures.

The Open Food System (OFS) ontology [21]: is part of the Open Food System project[10] which aims to build an ecosystem to facilitate the preparation of meals employing semi-automated cooking devices. It allows the elaboration of nutritional suggestions helping peoples to eat a balanced diet. The ontology is based on different modules integrating knowledge from different domains: *food* (their nutritive value but also the look, the smell and the taste they have), *preparation* (the basic techniques to prepare some food), *cooking* (the recipe with the ingredients and the different steps), *equipment* (the equipment used for the recipe) and *unit* (metrics of the cooking domain like "tablespoon" and international metrics like "milligram") domain.

C. Standards and Tools in the Food Domain

In the past, both national and international food classification and food description systems were developed. International classification systems such as the *Eurocode-2 food coding system* were formulated to meet regulatory requirements for foodstuffs.

LanguaL™: stands for "Langua aLimentaria" or "language of food". It is a method for describing, capturing and retrieving data about food. The thesaurus provides a standardized language for describing foods, specifically for classifying food products for information retrieval. It is used to index food information resource data sets in order to tag properties, e.g. *product type*, *food source*, *part of plant or animal*, etc., to the individual entries. The LanguaL™ thesaurus is used by many FCDBs in order to standardize the terminologies across the different countries and allows the mapping of ingredients and food terms to different languages.

Further tools: include the standard **EN 16104:2012 Food data - Structure and interchange format** [30]. The goal of this standard is to support the safe exchange of food data among a variety of stakeholders such as food manufacturers, authorities, retailers, dietitians, consumers, software developers, etc., with different requirements and intended uses. The standard defines a framework "*that facilitates and enables generation, compilation, dissemination and interchange of food data*". The standard enforces semantics and data structure for food data, a content of referenced controlled vocabularies, and XML encoding for interchange of food data. The UN FAO **INFOODS Food Component Tagnames** and **EuroFIR Food Data Transport Package** are further standards that support the interchange of food composition data.

IV. Discussion

Not surprisingly, the focus of the evaluated food domain models vary greatly due to the application domain and intended usage as well as the applied conceptualization paradigm. A summary of the different aspects is given in Table I.

User modeling is quite limited and often restricted to the definition of food items to avoid or recommended daily intake of certain nutrients. Exceptions are the *FOKB* [12] and *FOD ontology* [29] with a more extended modeling of the user in about health status, nutrition impairments, and dietary restrictions. Though deemed important, *cultural profiles* of food and

[7]www.edamam.com
[8]http://obofoundry.org/
[9]https://www.ebi.ac.uk/ols/ontologies/foodon
[10]http://www.openfoodsystem.com/

TABLE I. COMPARISON OF SEMANTIC FOOD KNOWLEDGE MODELING RESOURCES

Resource name	Application domain / Intended use	Concepts modeled	Advantages and Disadvantages
Food Product Ontology [25]	E-Commerce Shopping assistance	Packaged food product Basic food Dish	+ Extension of GoodReleations ontology + Flexible definition of attributes + Food product categories
LIRMM Food (Product) Ontology [26]	E-Commerce	Packaged food product	- Shallow description of packaged food - Fixed data attributes
FOODS [27]	Recipe/Dish rec. Cooking support Shopping support	Foods Ingredients Nutrition facts Recommended daily intakes	+ Combined with expert system + Cooking methods and prices + Personalization through ingredients preferred or to avoid - Only BMI taken into account
Edamam company project	Recipe rec. Cooking support	Food Recipes Ingredients Nutrition Information Allergies ...	+ Database of 540,000 food items + 1.7m nutritionally analyzed recipes + API for recipe search and analysis
Food Ontology Knowledge Base (FOKB) [12]	Single item rec.	Food product Ingredients Person Disease (Allergy)	+ User model + Classification of food items - Health information allergy focused
FoodOn [28]	"Farm to fork" Classification Cross-mapping Cooking support	Food product Food source Cooking process Cultural origins ...	+ Linked to LanguaL™ + Elaborate type classification + Elaborate relationship definition
Food Or Drink (FOD) ontology [29]	Cooking support Recipe recommendation	Food items, meals Recipe Flavour affinities	+ Scientifically sound modeling approach + Provides reasoning for cooking support and dietary restrictions
Open Food System (OFS) ontology [21]	Cooking support	Cooking Sensory aspects of food	+ Integration of cooking devices and further services + Recipe and sensory modeling - Not publicly available
AGROVOC	Mapping Translation	Food Nutrition Agriculture ...	+ Multi-lingual concept definition in 29 languages + 35,000 concepts available + Organized as SKOS + Published as linked open data set (LOD) + Aligned with 18 other SKOS through close/exact match
LanguaL™	Cross-mapping and tagging of FCDBs	Product type Food source Physical state Cooking method ...	+ Very exhaustive + Any food (or food product) can be systematically described by a combination of characteristics + These characteristics can be categorized into viewpoints and coded for computer processing

users rarely play a role and related concepts are only modeled in the relatively new *FoodOn* [28] ontology. Also, personal preferences like sensory performance are limited to the food domain, but not represented in the user domain [29], [21]. The authors are not aware of any user model that defines social inclusion in groups such as households or being an inhabitant of an care institution, e.g. being an elderly in need of care.

The *Food Product Ontology* [25] and *LIRMM Food (Product) Ontology* [26] focus on the conceptualization of consumer packed food products incorporating the product labeling information as required by law. It seems that the *Food Product Ontology* is more flexible as compared to *LIRMM Food (Product) Ontology*.

Recipes are modeled in [28], [29], [21], and the *Edamam company project*, whereas [28] and [29] provide models and inference support for deriving cooking instructions.

Supporting resources (AGROVOC, LanguaL™) are used for cross-mapping and translation of food related entities. *Cooking support* is the most prominent intended use (FOODS, Edamam, FoodOn, FOD, OFS), whereas FOODS, Edamam, and FOD target *recipe recommendation* and only Food Product Ontology and FOODS take *shopping assistance* into account. *Menu recommendation* is nowhere aimed for.

V. CONCLUSION AND FUTURE WORK

A holistic diet management should cover a broad variety of tasks including, *single item recommendation*, *dish/recipe recommendation*, *menu recommendation*, *shopping assistance*, and *cooking assistance* taking into account nutritional parameters, cultural and individual preferences, health and budgetary limitations, etc. In the framework of the LiFANA project we intend to continue with the following tasks to achieve a holistic semantic modeling approach enabling personalized dietary recommendations.

Together with the domain experts, we intend to develop a formal semantic food knowledge base of food and nutrition related domains by adapting and mapping concepts in existing ontologies and thesauri. The most promising modeling resources that we can base our work on include [29] and [28]. A large gap exists in appropriate user modeling so it is obvious that we must focus our work on that topic to allow for a proper personalization of the recommendations. Especially modeling of secondary users like informal carers needs to be elaborated.

Integration of external data sources, such as FCDB and CPG-databases, in a reliable and safe manner, i.e. a single knowledge base will be created that integrates existing, but currently not connected, data sources. Focus will be given on how to manage information coming from different databases with different values. The structure of the modular ontology presented in [21] is very interesting and allows to link different concepts of the cooking domain. But we didn't succeed to find more information or the resulting complete ontology of the project.

Acknowledgment

This work has been carried out in the context of Ambient Assisted Living project LiFANA www.lifana.eu. Also it was partially supported by a grant from the EuropeanUnion and National authorities, including the Luxembourgish Fonds National de la Recherche, Grant Number AAL-2017-013.

References

[1] R. Shepherd and R. Shepherd, "Resistance to changes in diet." *The Proceedings of the Nutrition Society*, vol. 61, pp. 267–272, 2002.

[2] A. Taweel, L. Barakat, S. Miles, T. Cioara, I. Anghel, A. R. H. Tawil, and I. Salomie, "A service-based system for malnutrition prevention and self-management," *Computer Standards and Interfaces*, vol. 48, pp. 225–233, 2016. [Online]. Available: http://dx.doi.org/10.1016/j.csi.2016.03.005

[3] A. G. Arens-Volland, L. Spassova, and T. Bohn, "Promising approaches of computer-supported dietary assessment and management-Current research status and available applications," 2015.

[4] A. Arens-Volland, L. Spassova, and N. Rösch, "Review of Mobile Health (mHealth) Solutions for Food-related Conditions and Nutritional Risk Factors," in *eTELEMED 2013, The Fifth International Conference on eHealth, Telemedicine, and Social Medicine*, feb 2013, pp. 284–289.

[5] H. Lease, G. A. Hendrie, A. A. M. Poelman, C. Delahunty, and D. N. Cox, "A Sensory-Diet database: A tool to characterise the sensory qualities of diets," *Food Quality and Preference*, vol. 49, no. 2016, pp. 20–32, 2016. [Online]. Available: http://dx.doi.org/10.1016/j.foodqual.2015.11.010

[6] V. Espín, M. V. Hurtado, and M. Noguera, "Nutrition for Elder Care: A nutritional semantic recommender system for the elderly," *Expert Systems*, vol. 33, no. 2, pp. 201–210, 2016.

[7] V. Espín, M. V. Hurtado, M. Noguera, and K. Benghazi, "Semantic-Based Recommendation of Nutrition Diets for the Elderly from Agroalimentary Thesauri," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2013, vol. 8132 LNAI, pp. 471–482. [Online]. Available: http://link.springer.com/10.1007/978-3-642-40769-7_41

[8] D. Ribeiro, J. Machado, J. Ribeiro, M. Vasconcelos, E. Vieira, and A. De Barros, "SousChef: Mobile meal recommender system for older adults," *ICT4AWE 2017 - Proceedings of the 3rd International Conference on Information and Communication Technologies for Ageing Well and e-Health*, no. Ict4awe, pp. 36–45, 2017. [Online]. Available: http://www.scitepress.org/Papers/2017/62819/62819.pdf

[9] V. Subramaniyaswamy, G. Manogaran, R. Logesh, V. Vijayakumar, N. Chilamkurti, D. Malathi, and N. Senthilselvan, "An ontology-driven personalized food recommendation in IoT-based healthcare system," *The Journal of Supercomputing*, mar 2018. [Online]. Available: https://doi.org/10.1007/s11227-018-2331-8 http://link.springer.com/10.1007/s11227-018-2331-8

[10] N. M. Yusof and S. A. M. Noah, "Semantically Enhanced Case Adaptation for Dietary Menu Recommendation of Diabetic Patients," in *Semantic Technology. JIST 2017*, ser. Lecture Notes in Computer Science, Y.-F. Li, W. Hu, J. S. Dong, G. Antoniou, Z. Wang, J. Sun, and Y. Liu, Eds., vol. 10055. Cham: Springer International Publishing, 2017, pp. 318–333. [Online]. Available: http://link.springer.com/10.1007/978-3-319-50112-3 http://link.springer.com/10.1007/978-3-319-70682-5_22

[11] G. Agapito, B. Calabrese, P. H. Guzzi, M. Cannataro, M. Simeoni, T. Lamprinoudi, G. Fuiano, and A. Pujia, "DIETOS : a recommender system for adaptive diet monitoring and personalized food suggestion," in *Fourth International IEEE Workshop on e-Health Pervasive Wireless Applications and Services*, 2016.

[12] D. Celik, "FoodWiki: Ontology-Driven Mobile Safe Food Consumption System." *TheScientificWorldJournal*, vol. 2015, p. 22, 2015.

[13] A. Kumar, P. Tanwar, and S. Nigam, "Survey and Evaluation of Food Recommendation Systems and Techniques," in *Computing for Sustainable Global Development (INDIACom), 2016 3rd International Conference on*, 2016, pp. 3592–3596. [Online]. Available: http://ieeexplore.ieee.org/document/7724932/

[14] C. Trattner and D. Elsweiler, "Food Recommender Systems: Important Contributions, Challenges and Future Research Directions," *Arxiv cs.IR*, pp. 1–16, nov 2017. [Online]. Available: http://arxiv.org/abs/1711.02760

[15] J. Freyne and S. Berkovsky, "Intelligent Food Planning : Personalized Recipe Recommendation," *Proceedings of the 15th international conference on Intelligent user interfaces*, pp. 321–324, 2010.

[16] D. Elsweiler and M. Harvey, "Towards Automatic Meal Plan Recommendations for Balanced Nutrition," in *RecSys 2015: Proceedings of the 9th ACM conference on Recommender systems*, 2015, pp. 313–316.

[17] M. Harvey and D. Elsweiler, "Automated Recommendation of Healthy , Personalised Meal Plans," in *RecSys 2015: Proceedings of the 9th ACM conference on Recommender systems*, 2015, pp. 327–328.

[18] S. Yamamoto, N. Kando, and T. Satoh, "Continuous Recipe Selection Model Based on Cooking History," in *Social Informatics - 8th International Conference, SocInfo 2016, Bellevue, WA, USA, November 11-14, 2016, Proceedings, Part I*, vol. 10046, no. 1, 2016, pp. 138–151. [Online]. Available: http://rd.springer.com/chapter/10.1007/978-3-319-47880-7_9

[19] K. A. Brown, L. Timotijević, M. Geurts, J. L. Arentoft, R. A. Dhonukshe-Rutten, L. Fezeu, P. Finglas, M. Laville, G. Perozzi, M. Ocké, K. Poppe, N. Slimani, H. M. Snoek, I. Tetens, P. van't Veer, C. Vors, and K. L. Zimmermann, "Concepts and procedures for mapping food and health research infrastructure: New insights from the EuroDISH project," *Trends in Food Science & Technology*, vol. 63, pp. 113–131, may 2017. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S0924224415301825

[20] M. Boulos, A. Yassine, S. Shirmohammadi, C. Namahoot, and M. Brückner, "Towards an "Internet of Food": Food Ontologies for the Internet of Things," *Future Internet*, vol. 7, no. 4, pp. 372–392, 2015. [Online]. Available: http://www.mdpi.com/1999-5903/7/4/372/

[21] S. Despres, "Construction d'une ontologie modulaire. Application au domaine de la cuisine numérique," *Revue d'intelligence artificielle*, vol. 30, no. 5, pp. 509–532, oct 2016. [Online]. Available: https://ria.revuesonline.com/article.jsp?articleId=36939

[22] J. P. Bantle, J. Wylie-Rosett, A. L. Albright, C. M. Apovian, N. G. Clark, M. J. Franz, B. J. Hoogwerf, A. H. Lichtenstein, E. Mayer-Davis, A. D. Mooradian, and M. L. Wheeler, "Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association." *Diabetes care*, vol. 31 Suppl 1, pp. S61–78, jan 2008. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/18165339

[23] N. M. Ryan, C. B. O'Donovan, H. Forster, C. Woolhead, and M. C. Walsh, "New tools for personalised nutrition: The Food4Me project," *Nutrition Bulletin*, vol. 40, no. 2, pp. 134–139, jun 2015. [Online]. Available: http://doi.wiley.com/10.1111/nbu.12143

[24] M. Gibney and M. C. Walsh, "Personalised Nutrition : paving a way to better population health A White Paper from the Food4Me project," Tech. Rep. March 2015, 2015.

[25] M. Kolchin and D. Zamula, "Food Product Ontology : Initial Implementation of a Vocabulary for Describing Food Products," *4Th International Conference of Fruct Association*, vol. 5, p. 191, 2013.

[26] F. Scharffe, S. Gigandet, E. Nauer, and M. Harrison, "Food Ontology," 2013. [Online]. Available: http://data.lirmm.fr/ontologies/food

[27] C. Snae and M. Bruckner, "FOODS: a food-oriented ontology-driven system," in *Second IEEE International Conference on Digital Ecosystems and Technologies (IEEE DEST 2008)*, 2008, pp. 168–176. [Online]. Available: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4635195

[28] R. Hoehndorf and M. Lange, "FoodOn - A farm to fork food ontology," 2018. [Online]. Available: http://foodontology.github.io/foodon/

[29] B. Krieg-Brückner, S. Autexier, M. Rink, and S. G. Nokam, "Formal Modelling for Cooking Assistance," *Software, Services and Systems - Essays Dedicated to Martin Wirsing on the Occasion of His Emeritation*, vol. 8950, pp. 355–376, 2015.

[30] European Committee for Standardization, *EN 16104:2012 - Food data - Structure and interchange format*. CEN, 2012.