Project ref no	AAL-2012-5-195
Project acronym	DIET4Elders
Project full title	Dynamic nutrItion bEhaviour awareness sysTem FOR theElders
Dissemination level	Public
Date of delivery	12/31/2014
Deliverable number	D3.1
Deliverable name	First version of the older adults dietary and self-feeding behaviour assessment techniques
Type	Report and prototype (R/P)
Status	Final
WP contributing to the deliverable	WP3
Main contributors	KCL, TUC
Other contributors	<ISOIN: COESCO: TUNSTALL>
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Keywords	<Dietary knowledge, nutrition care process ontology, behavior assessment techniques>
Abstract (for dissemination)	In this deliverable we present achievements obtained as a result of the work carried out in WP3. Specifically, we present our analysis for evaluating the diets of older adults, utilising suitable published recommendations, benchmarks and nutritional guidelines. Based on this analysis, we design and implement the Nutrition Care Process Ontology capturing nutrition-related knowledge, and comprised of four sub-ontologies: Nutrition Monitoring Ontology, Nutrition Assessment Ontology, Nutrition Problem Identification Ontology, and Nutrition Intervention Ontology. Finally, we introduce reasoning based mechanisms against the developed knowledge base for

	assessing the unhealthy short-term and long-term self-feeding behaviour of older adults and detecting nutrition-related problems.

Dynamic nutrition bEhaviour awareness system FOR the Elders

AAL-2012-5-195

Deliverable **D3.1**
First version of the older adults dietary and self-feeding behaviour assessment techniques

Public

VERSION HISTORY

Version	Edited by	Date	Description
0.1	KCL	24 October 2014	Table of Contents
0.2	KCL, TUC	28 November 2014	Deliverable version for peer review
0.3	ISOIN	03 December 2014	Reviewed version
0.4	COESCO	10 December 2014	Reviewed version
0.5	KCL	12 December 2014	Pre-final version
1.0	KCL	26 December 2014	Final version

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1. Introduction

Malnutrition can be defined as "a state of nutrition in which a deficiency, excess or imbalance of energy, protein, and other nutrients causes measurable adverse effects on body form (body shape, size and composition), function, and clinical outcome" [1]. Older adults are particularly vulnerable to malnutrition due to a number of age-related risk factors, with various studies revealing escalating rates of malnutrition in the older population. For example, according to the British Association for Parenteral and Enteral Nutrition (BAPEN) [2], malnutrition affects over 3 million people in the United Kingdom alone, and of these, about 1.3 million are over the age of 65.

If unmanaged, malnutrition may contribute to significant impact on the older person's health (such as exacerbation of chronic conditions, delay in recovery from illness, etc.), thus causing significant increases in related healthcare costs. In fact, the cost associated with malnutrition in Europe is estimated to amount to a staggering 170 billion euro each year [3]. The rapid identification of malnutrition and early prevention through the provision of nutritional assistance to the elderly would thus help to avoid such high public health costs, and enhance both the mental and physical conditions of older adults and their quality of life.

In response, the DIET4Elders project aims to assist older adults and their informal carers to detect and prevent the instauration of malnutrition, and to help nutritionists to monitor and manage the diet of older adults. This work package contributes towards achieving these goals via: constructing a dietary knowledge base capturing various aspects that are relevant to older adults and their nutrition; and developing suitable reasoning techniques (against such knowledge base) to assess the elderly's short term and long term self-feeding behaviour and to identify potential nutrition associated problems.

In particular, led by nutritionists, we first investigate benchmarks and nutritional guidelines to evaluate diets based on published recommendations suitable for older people, as well as identify suitable nutrition problems and interventions for the elder end user. We

also define the scope and requirements of the nutritionist end user. These are detailed in **Chapter 2**.

Such nutrition related information (provided by nutritionists) is utilised to construct a corresponding computational dietary knowledge representation via designing and implementing the Nutrition Care Process Ontology consisting of four sub-ontologies: Nutrition Monitoring Ontology, Nutrition Assessment Ontology, Nutrition Problem Identification Ontology, and Nutrition Intervention Ontology. The Nutrition Monitoring Ontology defines and semantically represents information regarding the older adult relevant for assessing their nutrition and self-feeding behavior. The Nutrition Assessment Ontology covers information facilitating the assessment of older adult food intake and associated nutritional values. The Nutrition Problem Identification Ontology captures potential nutrition related problems and the associated symptoms. Finally, the Nutrition Intervention Ontology models suitable intervention actions for identified nutrition problems and unhealthy behavior. These ontologies are detailed in **Chapter 3**.

Based on the Nutrition Care Process Ontology, a reasoning-based infrastructure and reasoning mechanisms are introduced in order to assess the short term and long term older adult behavior, identifying unhealthy patterns and proactively detecting the early instauration of specific nutrition related problems. These are detailed in **Chapter 4**.

2. Clinically-informed Diet Knowledge and Scenarios

Led by nutritionists, our goal here is to investigate and develop clinically-informed diet knowledge based on a number of selected scenarios relevant to older adults. The output of this task will feed into constructing a computational representation of the knowledge.

In particular, we first provide a set of guidance notes on the Nutrition Care Process that facilitate ontological knowledge construction, followed by a summary of the nutritionist end user requirements.

2.1 Nutrition Care Process

There are a number of standardised models of the nutrition care planning process, most notably the Academy of Nutrition and Dietetics' Nutrition Care Process and Model [8]. The British Dietetic Association has a similar version, known as the Model and Process for Nutrition and Dietetic Care [5], and dietetic associations from Canada and Australia use similar processes and models. All share similar principles. The international dietetics community is working to develop a standardised language for documenting the nutrition care process [9]. Within Europe, take up by the profession has been slower however there is a vision for the adoption of a standardised care process and language to be used by all dietitians, and in the training of dietitians, by 2020 [6].

Nutrition care planning is a cyclical and systematic process (Figure 1), with each stage dependent on those preceding it. The four stages are:

- Assessment (see Figure 2)
- Problem identification - development of a dietary plan (see Figure 3)
- Intervention implementation (see Figure 4)
- Monitoring (see Figure 5)

The final stage (monitoring) feeds into the first stage again, i.e. it triggers a 're-assessment' to determine if the previous plan is still relevant or if changes need to be made to reflect the progression of previously identified, or the development of new, nutritional

problems. Factors influencing the implementation of the intervention (for example social, financial changes) are also identified during the monitoring stage.

In practice, screening in the community or by non-nutrition specialists triggers a referral to a nutritionist or dietitian for more in depth assessment and a 'nutrition care plan' is then developed. Hence screening is almost a 'pre-step' of the nutrition care process (Figure 1).

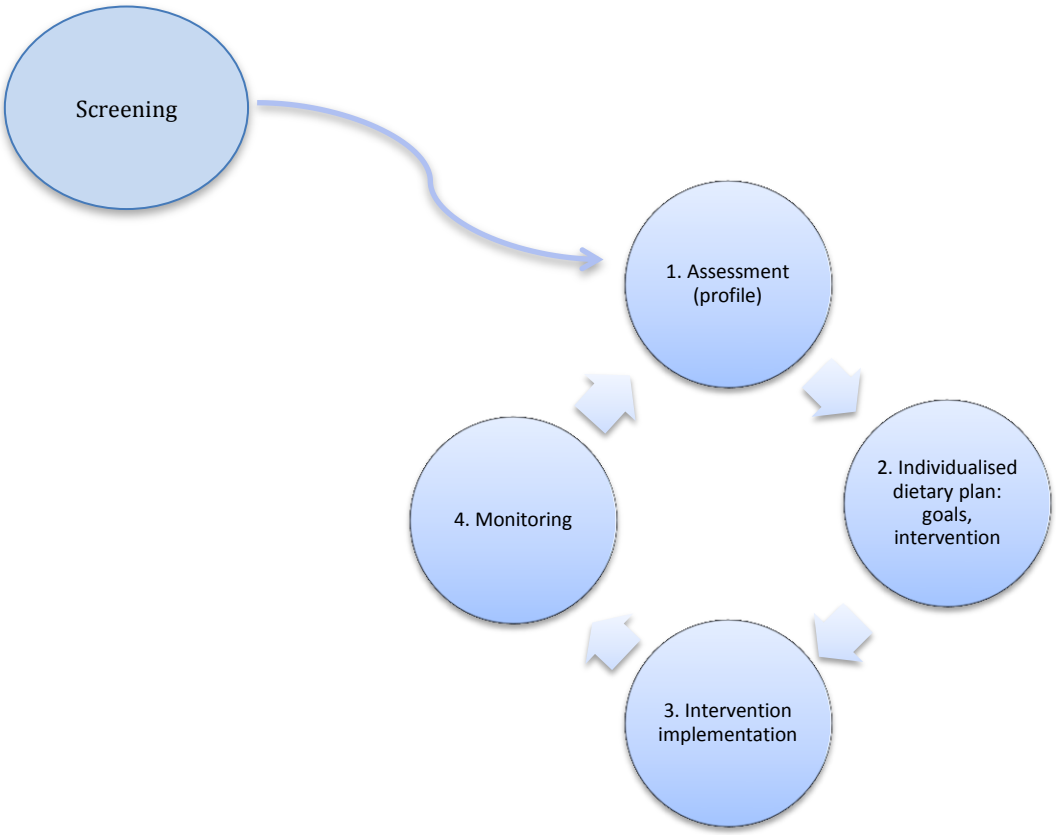


Figure 1: Nutrition care process and relationship with screening

2.1.1 Use of the NCP in the Diet4Elders Ontology

Whilst the NCP process is designed for individuals, groups and communities, its use in the ontology for Diet4Elders may need to be simplified to enable the automation of the process and to ensure individuals requiring specialist nutrition and dietetic input are able to

be identified and managed by a suitably qualified nutrition professional. Ideally the programme will allow the tailoring of automated processes for those individuals.

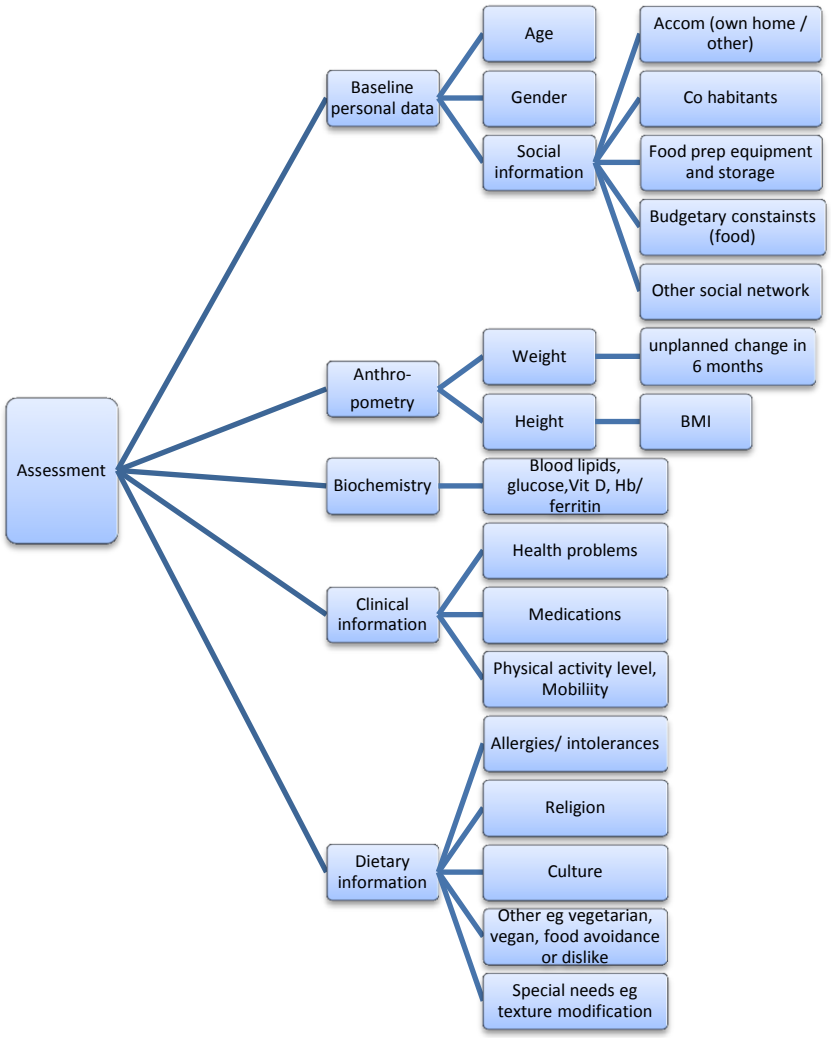


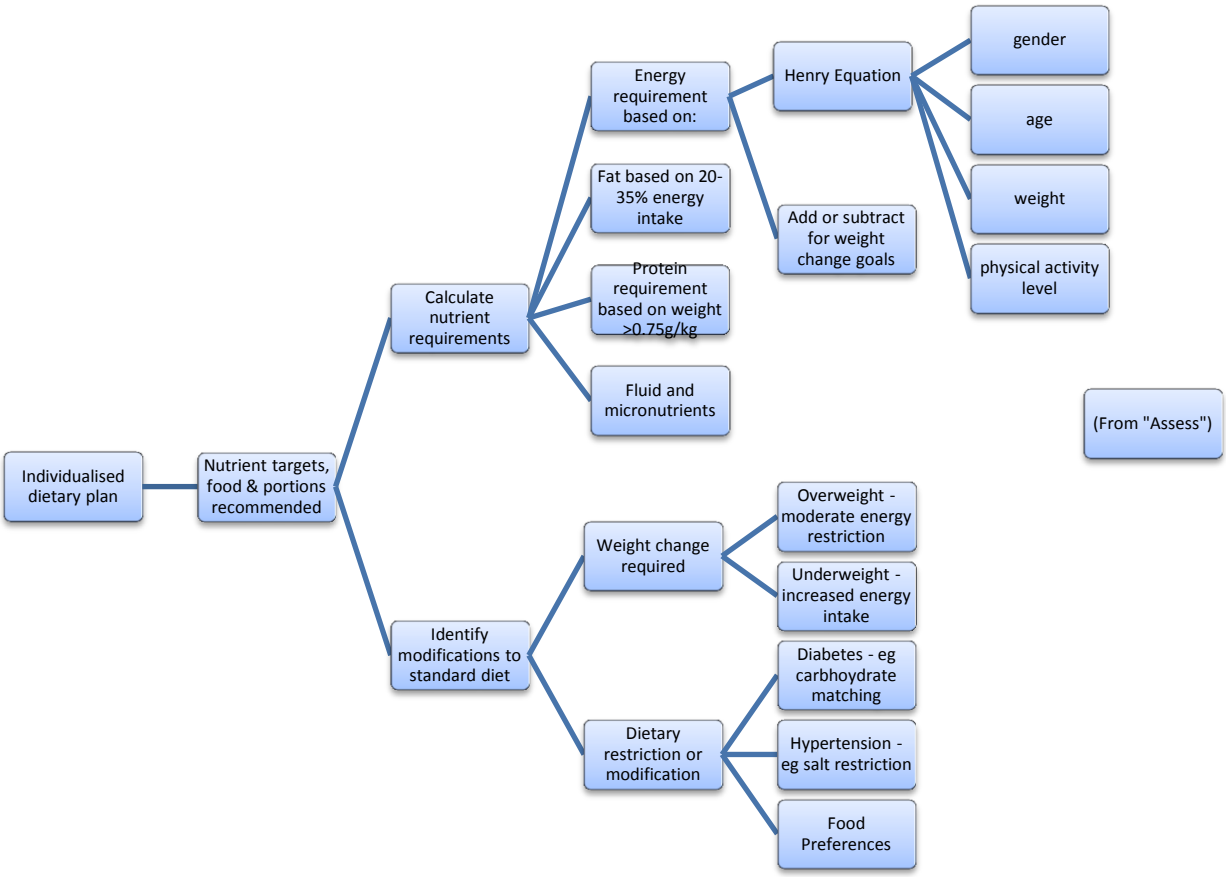
Figure 2: Assessment stage of the nutrition care process

2.1.2 Nutrition Care Process Stage 1: Assessment

The **assessment** stage will inform the profile in the ontology, and is based on information collected to register individuals on to the Diet4Elders system. Automation of the interpretation of the user information is a key part of the process.

Information required will include **personal information** such as age, gender, social and lifestyle information (including living arrangements, financial context, skills and

equipment for food preparation, supports already in place including family and wider social



network).

Figure 3: Problem identification stage of the nutrition care process

The rest of the assessment is based on the "ABCD approach" (which includes collection of anthropometry, biochemistry, clinical and dietary information) as outlined below.

i. **Anthropometry** is the measurement of different aspects of the human body. In the older population the most important data to be collected will usually be 'measured' weight and height, although 'proxy' or 'estimated' measures can be used particularly for height which may be more difficult to measure. Proxy measures of height include ulna length and demi span which are

measures that are relatively simple and require only a small amount of training to administer.

Anthropometry information needs to be interpreted to inform the assessment; commonly body mass index (BMI, weight/ height) and any percentage change in weight (previous – current weight/ previous weight x 100) in the preceding 6 months is calculated.

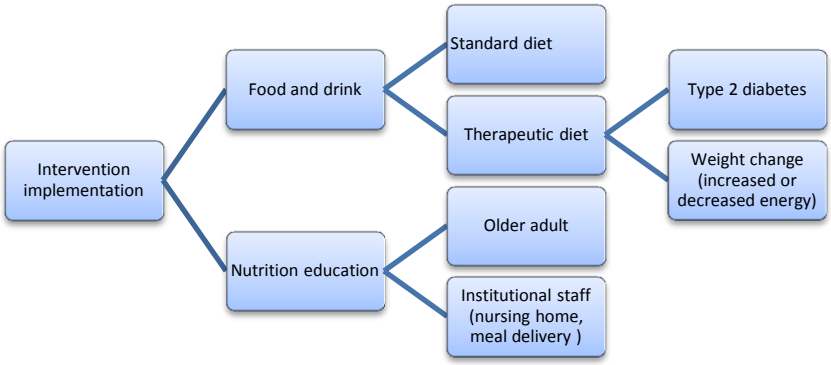


Figure 4: Intervention implementation stage of the nutrition care process

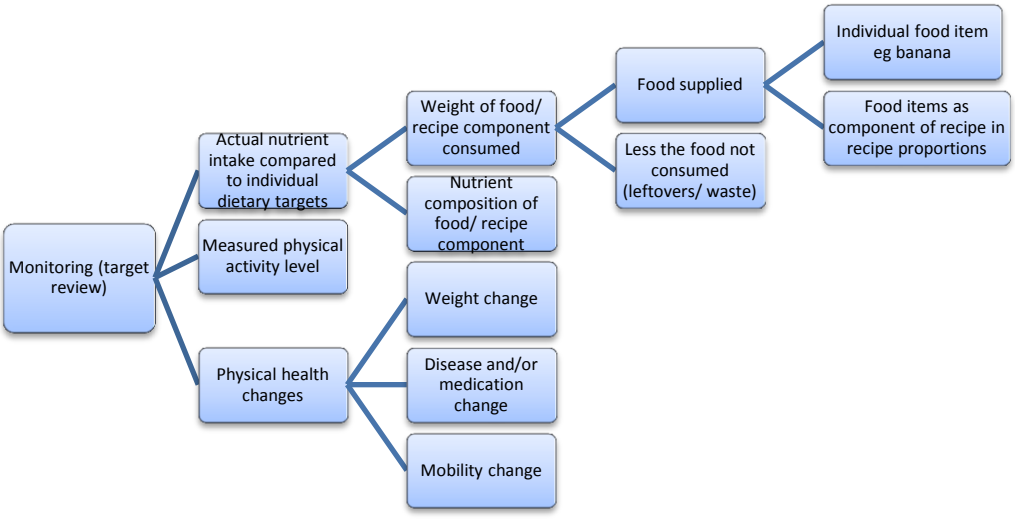


Figure 5: Monitoring stage of the nutrition care process

ii. **Biochemistry** information (if available) is collected to identify those individuals requiring intensive follow up (individualised care by a nutrition professional) and flag up where dietary modification might be targeted.

It is unlikely that older people living in the community will be able to provide blood chemistry results for this part of the assessment. However those being seen by a nutritionist or dietitian with a referral from a doctor/general practitioner may want the Diet4Elders system to record this information. Typically in the older age group blood chemistry results may include blood lipids (cholesterol, triglycerides), blood glucose, or full blood counts (which includes white cell count, red blood cell count, and haemoglobin levels), and - if diabetes is present - glycosylated haemoglobin (HbA1c).

These tests must be ordered by a doctor but are useful adjuncts to the nutritional assessment; an evaluation of whether dietary modification might help to address values outside of the normal range is made (dietary modification may be instead of or in conjunction with medication). They are also very useful outcome indicators to evaluate nutrition and dietary care.

The absence of biochemistry data does not preclude further assessment.

iii. **Clinical** information collected includes details of health problems including normal ageing processes likely to affect food intake e.g. poor dentition, problems with digestion and information on mobility / function (including activities of daily life if available), medical diagnoses and/or information on treatment from other health professionals such as physiotherapists, speech and language therapists (who may prescribe food and drink texture modifications), home care nurses etc., use of prescribed and over the counter medications and supplements (if available from the general practitioner).

As blood pressure is known to increase with age, it could be useful to consider blood pressure monitoring by older people in their homes as part of the Diet4Elders system, even if the individual is not identified as needing

intensive support. This is because there is a general age-related increase in blood pressure; and in the 'very old' blood pressure becomes less stable.

iv. **Dietary** and food preference information collected including likes/ dislikes, unsuitable foods (due to texture modification prescriptions, allergies, intolerances, personal or religious and cultural exclusions) and details of texture modification prescriptions (e.g. soft foods, pureed food, thickened drinks) is collected to ensure these are reflected in the planning and implementation of the intervention.

(a) Standard users: For most older people living in the community (**standard users**), an assessment of dietary quality (using the 14-item Mediterranean Diet Assessment Tool, Table 1) should be undertaken automatically.

Where full dietary intake has been assessed using the Diet4Elders system (e.g. food intake has been entered by the system as food is eaten, for the whole day), a quantitative assessment of estimated intake against nutrient benchmarks (Table 2) should be automated by the Diet4Elders system. If only part of a day's intake is available, then nutrient benchmarks for a single meal should be compared (Table 3).

(b) Intensive users: For those identified as requiring intensive support (**intensive users**), an option for the nutritionist to individually calculate energy and protein goals (that is, bypass the benchmarks for energy and protein, and generate individualised targets) should be available.

The Diet4Elders system could do this automatically using an appropriate energy equation (including a factor for physical activity) and based on 0.75g protein per kg per day. The system should then be able to flag up shortfalls in the individual-specific targets for energy and protein. Benchmarks in Table 2 should be used for other nutrients with an option for the nutrition professional to override these if required.

If only part of a day's intake is available, then nutrient benchmarks for a single meal should be compared (Table 3).

2.1.3 Nutrition Care Process Stage 2: Potential problem identification

This is the first component of what is referred to as the Nutrition Diagnosis in the Academy of Nutrition and Dietetic Nutrition Care Process and Model [8].

The nutrition diagnosis is made up of three components (using the acronym "PASS"): **P**roblem – describes the alteration in the person's nutritional status; **A**etiology – cause or contributing risk factors; and **S**igns and **S**ymptoms – defining characteristics.

The Diet4Elders system will use only the problem identification component of the nutrition diagnosis for standard elder end-users (those older people living in the community and not identified as requiring intensive support from a nutrition professional). However there should be an option for the full nutrition diagnosis to be entered manually by the nutritionist for intensive elder end-users, which could increase the market appeal of the system.

There are standard 'diagnostic terms' to be used in each of the components of the diagnosis, which come form the "Nutrition Diagnostic Terminology" developed as part of the Standardised Language for the Nutrition Care Process[4]. It is proposed that standardised language terms for a limited number of problems will be included (and automated) in the Diet4Elders System (Table 4). The full terminology includes around 60 approved terms.

Table 1: 14-item Mediterranean Diet Adherence Score

Questions	Criteria for 1 point
1. Do you use olive oil as main culinary fat?	Yes
2. How much olive oil do you consume in a given day (including oil used for frying, salads, out-of-house meals, etc.)?	≥ 4 tablespoons
3. How many vegetable servings do you consume per day (1 serving: 200g; consider side dishes as half a serving)	≥ 2 (≥ 1 portion raw or as a salad)
4. How many fruit units (portions) (including natural fruit juices) do you consume per day?	≥ 3
5. How many servings of red meat, hamburger, or meat products (ham, sausage, etc.) do you consume per day (1	< 1

serving: 100 – 150g).	
6. How many servings of butter, margarine or cream do you consumer per day (1 serving: 12 g)	< 1
7. How many sweet or carbonated beverages do you drink per day?	< 1
8. How much wine do you drink per week?	≥ 7 glasses
9. How many servings of legumes do you consume per week? (1 serving: 150g)	≥ 3
10. How many servings of fish or shellfish do you consume per week? (1 serving 100-150g fish or 4-5 units (pieces) or 200g of shellfish)	≥ 3
11. How many times per week do you consume commercial sweets or pastries (not homemade), such as cakes, cookies, biscuits, or custard?	< 3
12. How many servings of nuts (including peanuts) do you consume per week? (1 serving 30g)	≥ 3
13. Do you preferentially consume chicken, turkey, or rabbit meat instead of veal, pork, hamburger or sausage?	Yes
14. How many times per week do you consume vegetables, pasta, rice, or other dishes seasoned with sofrito (sauce made with tomato and onion, leek, or garlic and simmered with olive oil)?	≥ 2

Source [7]

Table 2: Benchmarks and dietary recommendations for older people

BMI	Body mass index (BMI) should be in the range of 20-30 kg/m2
Energy	Recommendation: Energy intake in balance with energy expenditure, to promote weight maintenance.
	Energy requirements estimated on an individualised basis using a physical activity factor and the Henry (2005) equations (see Table 2)
	Generic benchmarks for energy intake: Men 9.8 MJ/day Women 8.0 MJ/day
Total fat	20-35% energy
Saturated fatty acids	< 11% energy

Trans fatty acids	< 1% energy
Protein	Protein requirements estimated on an individualised basis: > 0.75g/kg body weight / day
	Generic benchmarks for protein intake: Men 53g / day Women 47g / day
Potassium	> 3.5g/d (majority supplied by fruit and vegetables)
Calcium	> 700 mg/ day
Vitamin D	10 micrograms/day (probably only achieved by supplementation)
Salt	< 6 g / day (equivalent to 2.4g sodium/ day)
Alcohol*	Men < 28 units / week Women < 21 units/ week
Fluid	Adequate fluid intake.
	Generic benchmarks for fluid: Men 2.5 L / day Women 2L / day Additional fluids will be required in hot weather.

Table 3: Generic nutrient benchmarks by meal for older people

	Total energy (approx.)	**Protein (approx.)**
BREAKFAST: E.g. fruit juice, cereal and semi-skimmed milk, bread and spread, preserves	400 kcal	5.0g
MAIN MEALS AND DESSERTS: Total of two main courses and desserts offered each day should average out to meet energy and	1050 kcal	29.0 g

protein specified. *(If providing one meal, divide by half.)*	*(1 meal:* *525 kcal)*	*(1 meal:* *14 g)*
HIGHER ENERGY SNACKS INCLUDING A SUPPER SNACK: Total of two to three daily; the total nutrients provided should average out to meet the energy and protein specified.	400 kcal	3.0g
MILK FOR DRINKS 400ml semi-skimmed/skimmed milk Minimum of Fluid intake 6-8 glasses of water, juice and milky drinks Plus CHEESE A small portion (15g or half a matchbox) (OR additional 150ml milk)	190 kcal 60 kcal	14g 4.0g
For practical and working purposes the total to be provided is rounded to 2100 kcal and 55g protein. These are minimum values and not targets.		

Table 4: Diet4Elders Automated Nutrition Problems (with Rule Definitions)

Automated Nutrition Problem	Rule definition
Predicted sub-optimal energy intake	Weight loss of 3kg or more in the past month (but only if this is unintended i.e. that there has not been a goal of weight loss)
Predicted excessive energy intake	Weight gain of 3kg or more in the past month (but

	only if this is unintended i.e. that there has not been a goal of weight gain)
Inadequate fluid intake	Reporting less than six glasses of fluid (in total) per day
Less than optimal intake of types of fats	Reporting a 7-day average saturated fat intake of greater than 11% of fat
Swallowing difficulty	Reporting a swallowing difficulty in questions marked ** in Table 6
Underweight	BMI of less than 18.5 kg/m2
Overweight	BMI of 25.0 – 29.9 kg/m2
Obese	BMI of 30.0 kg/m2 and greater
Impaired ability to prepare foods/ meals	A non-report of more than two items in the questions marked * in Table 6
Self-feeding difficulty	A report of one or more items in the questions marked ** in Table 6
No nutrition problem at this time	None of the above

2.1.4 Nutrition Care Process Stage 3: Intervention

This stage can be broken down into two steps: Planning and Implementing.

a) Step 1: Planning the intervention (diet)

This step aims to identify actions to address the potential problem identified as part of Stage 2 of the NCP. The plan should be directed at changing something, with set **goals and expected outcomes**.

Ideally the plan should be developed in conjunction with / by the older person (and carers or family), as well as reflecting the evidence base and clinical guidelines.

For goals /intervention planning, the following factors are considered:

- Changing nutrient or food provided to affect intake
- Influence nutrition related knowledge or behaviour
- Change to environment
- Access to supportive care and services

To encourage user involvement, the Diet4Elders system will incorporate a 'pool of goals and intervention actions' to be offered to the user, who then would have the option to select 2-3 preferred interventions. Table 5 provides a list of goals for the intervention stage in Diet4Elders.

Expected outcomes will also be required, as these inform the final stage (monitoring) of the Nutrition Care Process.

Example Problem	**Example Expected Outcome (to base intervention on)**
Unintentional weight loss of 3kg or more in the past month	No further weight loss OR Weight gain back to baseline weight
Underweight (BMI<18.5 kg/m^2)	No further reduction in BMI

b) Step 2: Implementing the intervention

The intervention implementation is usually decided as a result of a collaboration of the older person with carers, family and sometimes a number of other professionals and services. The older person should be central and have input into selecting and adapting the strategies for them to achieve the goals agreed on in the earlier stages. Table 5 provides a pool of actions for the intervention stage in Diet4Elders.

The interventions implemented should be targeted to the individual's potential problems and plan. Ideally these could link in with local and country-specific resources and services e.g. tips/ suggestions for improving rest of the day's meals and/or age appropriate physical activity/ social connection. Local and country-specific resources and services could provide details of activities and support available for the older person via the app.

Table 5: Intervention options to be automated by Diet4Elders

Intervention	**Automated goals**	**Examples of D4E intervention action options**
Food delivery		
Meals and snacks	Regular meals and/or Regular snacks: - general healthy diet - modify distribution, type or amount of food within meals or snacks - encourage/ provide specific foods, beverages or food groups	Provide additional snack foods that are high in energy and protein (and in line with older person's preferences) e.g. cheese with biscuits, yoghurt, custard, scones or pancakes
Feeding assistance	Assistance with eating: - special equipment - feeding position recommendation - meal set up	Involve carers and family. Incorporate some of the strategies recommended by the Dementia Mealtime Assistance Tool (DMAT) or similar
Feeding environment	Improvement to eating environment: - lighting - distractions - table height - table set up - room temperature	Incorporate tips and strategies from DMAT or similar.
Nutrition Education	Brief Nutrition Education: - build or reinforce basic	E.g. Video clips with tips, recipes, skills education;

	nutrition related knowledge	highlighting foods on the menu that meet goals set

2.1.5 Nutrition Care Process Stage 4: Monitoring

Monitoring allows the tracking of progress at defined intervals against the goals set in Stage 3 (a) of the NCP. It also keeps track of changes in other measurements taken at baseline, even if these were normal and not part of previously defined goals. These allow an evaluation of the benefits of the Diet4Elders system in prevention of nutrition related problems.

Monitoring usually requires a comparison of the monitoring measures at a given time point against:

- Previous measurements, as changes over time might suggest the development of a problem e.g. malnutrition, overweight.
- Previous goals [from Stage 3 (a)], as this allows evaluation of the success or otherwise of the interventions implemented in Step 3 (b).
- Nutrient benchmarks (and possibly other reference standards, e.g. for weight and BMI) as these indicate where the individual may not conform to population norms and ideals.

Monitoring is a two step process, aimed at identifying short term factors influencing success or problems with implementation, and more medium to long term (outcome focussed) factors.

(a) Step 1 Monitor process of implementation (short term)

- Check older person's understanding and ability to comply with the strategies selected.
- Are there any unintended consequences of the strategy? These could be physical, social, or psychological.
- Are changes occurring and in the right direction? These could be physical, dietary, or well being.
- Are there new factors that might make the selected strategies less useful or might explain lack of progress?

(b) Step 2 Measure outcomes (medium or long term)

- Select outcome indicators related to the signs and symptoms (from the diagnosis), nutrition goals, medical diagnosis or quality management goals

OUTCOME data:

- Weight change
- Changes to home blood pressure monitoring results, reported problems affecting food intake
- Mediterranean diet assessment tool score
- Nutrient intake and comparison with benchmarks

2.2 Nutritionist User Requirements

2.2.1 Overview of potential nutritional professional users of Diet4Elders

Nutritionists and dietitians working in a variety of roles are potential users of Diet4Elders. They may be directly employed, employed on a freelance basis, or use nutrition and dietetic assistants as their proxies to follow up clients in the community setting.

(a) Directly employed nutrition professionals: Nutritionists and dietitians may be employed directly by organisations providing delivered meal services, providing catering to supported accommodation facilities such as care homes, as well as day centres and acute hospital services.

(b) Freelance nutritional professionals: There may also be nutritionists and dietitians working on a freelance basis, seeing individuals directly, or providing consultancy services to organisations providing the services outlined above.

(c) Nutrition or dietetic assistants as proxies for nutritionists and dietitians: Within the NHS in the UK, dietetic hospital departments are funding dietetic assistants to follow up patients discharged from the acute setting in the older person's own home in an effort to prevent malnutrition and avoid readmission to hospital as a result of poor nutrition at home.

Typically any of the users identified in (1) above will have clients divided into those that are 'routine' and those that require more intensive support. Ideally then, the

Diet4Elders system should allow the nutritionist to define a client as either a standard or intensive client.

i. Standard Client

- Not identified as being at high risk of nutritional problems including malnutrition.
- The majority of nutritional input is automated.
- The Diet4Elders system uses generic benchmarks and standardised terms for nutrient requirements, problem identification, intervention planning and strategies.

(This should be the majority of users for pilot phase of D4E.)

ii. Intensive Client

- Identified as higher risk or with multiple nutritional problems, and therefore requiring more personalised nutritional input
- Some of the nutritional input could be automated as for standard users, but the nutritionist/ dietitian is able to over ride the automated options, be able to monitor more frequently, make changes to generic diet benchmarks, problems, and interventions. Would also be useful to allow a full nutrition diagnosis statement to be input directly by the nutritionist for these users if required.

2.2.2 Needs of the nutritionist user

i. Interaction

Diet4Elders should provide the nutritionist with a way to interact with standard and intensive clients (older people) as well as with food service providers, carers, social services and possibly other health care professionals such as general practitioners.

ii. Monitoring

For standard clients, the system should be able to be used autonomously by the older person, with easy monitoring on screen by the nutritionist.

For more intensive clients, a higher level of support and monitoring should be possible, and a 'red flag' for those clients would be useful to facilitate this.

The nutritionist will want to monitor and access information on individuals in the Diet4Elders system, but will also want to generate reports with data on outcomes for users at a group level to demonstrate the effectiveness of the system and service provided by the nutritionist (see iii below).

iii. Reports

The nutritionist may want to access reports, including the following, from the Diet4Elders system:

- Reports on baseline information for new clients as they are registered, and on existing clients as their assessment information is updated and as they provide feedback and food preferences through the system.
- Monitoring reports for individuals, with flags on clients who have not improved or have worsened in their nutritional assessment parameters and outcomes.
- Regular reports on food intake, change in weight, other health data, outcome measures is desirable.

2.2.3 Potential functionality required by nutritionist users

i. Assessment stage of Nutrition Care Process

- Regular report of new users entering the system. The frequency of reports should be able to be adjusted by the nutritionist, to meet the needs of their client base. For example a nutritionist working for a delivered meals service may require weekly reports on new clients; whereas a hospital dietitian may require

daily reports on new clients. A list of clients potentially requiring closer assessment (as indicated in Table 6) would be useful as helpful to flag clients requiring more intensive follow up– perhaps post the end of the project when looking at increasing marketability of the system. The type of information reported should be able to be selected by the nutritionist, from all of the profile information entered when a new client is registered.

- Categorisation of clients. There should be a function in the system to categorise new clients that the nutritionist identifies as intensive. Ideally, the system will flag those users in the regular reports of new users.
- Interaction with users/ others. Could the Diet4Elders system allow the nutritionist to request additional information from the user, the meal delivery service, carer or family? This would enable further assessment to inform categorisation. Not needed in pilot but something to consider when going out to market. Typically, the nutritionist may want additional information or details on special health factors, economic constraints, or environment.
- The ability to individualise nutrient requirements, especially for energy and protein, for intensive clients. Generic benchmarks are appropriate for standard clients, however having the facility for the system to calculate individual energy and protein requirements for intensive clients would be desirable for some nutritionists. The ability to over-ride other nutrient requirements, to tailor them from the generic benchmarks would also be useful.

Table 6: Assessment questions to identify potentially intensive clients (reporting)

Assessment Question	**User response options (multiple selections possible)**	**Criteria for flagging**
*Which of the following have you made for yourself at any time this week?	Hot drink Toast Microwave 'ready' meal Fresh or frozen vegetables cooked on the hob or in oven Fresh or frozen meat cooked on the hob or in the	If one or more NOT selected, flag in nutritionist report.

	oven	
**Which of these problems do you currently have?	Breathless with minimal effort Problems with your teeth Sore mouth Poor eyesight Hand tremors or shakes Difficulty swallowing Other (free comments?)	If two or more selected, flag in nutritionist report.

ii. Potential problem identification stage of Nutrition Care Process

- Problem Identification (default/ for piloting). The system should generate a limited list of problems (drawn from the International Dietetic and Nutrition Terminology; IDNT*) which are automated according to assessment information (Table 4). Nutritionist and/or client should be able to select priority problem/s to inform intervention (requires interaction by each and with each of nutritionist and client). Note that there are copyright restrictions with full use of IDNT.
- Full Nutrition Diagnosis. The system could automatically prompt for problems as above, however more problems could be incorporated, AND the system could allow the inclusion of aetiology (cause) and signs and symptoms to generate a full nutrition diagnosis for those nutritionists who wish to use this function with intensive clients. (This option may require copyright permission from the Academy of Nutrition and Dietetics).

iii. Nutritional intervention stage of Nutrition Care Process

The nutritionist user will use this part of the Diet4Elders system as the 'action' area, and will need this to communicate intervention plans between the nutritionist and the older person themselves (standard and intensive clients), carers, and people working in food and delivery services.

There are two steps to this stage. Firstly planning the intervention, and then evaluating the processes involved in carrying out the intervention (i.e. that what should have happened, has happened).

- Automated intervention action options. For standard clients, the use of automated intervention options limited to the domains of Food Delivery/ Intake and Nutrition Education, with the end user predominantly selecting goals and actions according to preference (Table 7).
- Flexible / individualised intervention action options. For intensive clients, the capability for the nutritionist to interact with the user and develop individualised goals and desired outcomes (i.e. not fully automated). This option would increase the marketability of the product to freelance and acute/ sub-acute dietitians, and may come after the project completion. The full spectrum of domains captured in the International Dietetic and Nutrition Terminology (IDNT)* would be used, i.e.:
    - Food delivery/ intake
    - Nutrition education
    - Nutrition counselling
    - Coordination of nutrition care

    *Note that there are copyright considerations with full use of the IDNT

Table 7: Automated intervention actions for standard clients

Domain	Standardised goals	Standardised actions
Food Delivery/ Intake Meals and snacks	Regular meals and/or Regular snacks: - encourage/ provide specific foods, beverages or food groups	• Provide additional snack foods that are high in energy and protein e.g. cheese with biscuits, yoghurt, custard, scones or pancakes. • Prompt user to have additional snack foods (as above).
Nutrition Education	Brief Nutrition Education: - build or reinforce basic nutrition related knowledge	• E.g. Video clips with tips, recipes, skills education; highlighting foods on the menu that meet goals set

The nutritionist will also need to use the system for process evaluation purposes, i.e. they will need to see that the plan has been carried out (for example, that a meal with additional snack items has been delivered as agreed), and check that any existing problem is identified and rectified. In this part of the system, it is important that the client (older person) can feedback on the acceptability of the intervention, as well as communicate any practical issues with the implementation of it.

iv. Monitoring stage of Nutrition Care Process

- Periodical report on follow up values for assessment parameters collected on users such as weight, food intake, problems affecting nutritional intake. As with Assessment reports, the frequency of reports should be able to be adjusted by the nutritionist, to meet the needs of their client base. In addition, the type of information reported should be able to be selected by the nutritionist, from all of the profile information entered when a new client is registered.
- Monitoring report on client outcomes (i.e. whether goals are being achieved or not achieved and re-measure diet quality using Mediterranean Diet Score). Flag up clients where goals are not consistently being achieved. Frequency of these reports should be able to be amended, perhaps 3-6 monthly for standard clients and more frequently if there are intensive clients being monitored.
- More comprehensive assessment of actual food consumed. There may be a market need to have more comprehensive assessment of food intake for some clients (e.g. intensive clients). Ideally for the nutritionist, dietary analysis of food intake would be fully automated (using standardised portion sizes) including recipe analysis.
- Identification of any unintended consequences of actions taken during the nutrition care process. Ideally outcomes and monitoring should pick up changes to the client's mood, quality of life, and satisfaction with services. Diet4Elders system should include a formal user/ carer evaluation to inform this component, as the nutritionist user will find this useful.
- Group reporting function. In addition to reports on individual clients using Diet4Elders, the system needs to be able to report on the users as a group so that

the effectiveness of Diet4Elders can be demonstrated. It has the potential to provide rich information on the group of people using the system, for example the characteristics of older people living in their own homes with support services is poorly understood. The change in the data on the group relating to the assessment and monitoring stages over time could inform more detailed evaluation of the Diet4Elders system and services.

3. Nutrition Care Process Ontology

Based on the nutrition process analysis presented above, the goal of this chapter is to investigate an appropriate computational representation for the clinically informed diet knowledge, and to construct the corresponding ontology/knowledge base.

A common state of the art approach to represent knowledge of a specific domain (in this case the older adult nutrition process domain) is in form of ontologies [10]. The main idea is to establish standard models, taxonomies, vocabularies and domain terminology. These can be further used to infer new knowledge and relations in the modeled domain.

Ontologies are a way to abstract data in a way similar to the real world model by using classes, individuals, data properties and object properties[1].

The *concept of class* used in defining ontologies is similar with the concept of class used in the object oriented programming languages. Classes are templates or blue prints that represent a group of entities that have the same properties. Data from the real world may be classified by using a hierarchy of classes and subclasses.

Individuals are instances of classes, and can have data properties and object properties. The line between individuals and classes is hard to determine, and sometimes the same entity may be represented in both ways.

Data properties are similar with the fields from object oriented languages, and can have different types such as Boolean, integer, string, etc.

Object properties represent relations between individuals.

When defining object properties or data properties, two important concepts are very important: the domain of the property and the range of the property. The domain represents the set of classes or data types to which the property refers, while the range represents the values that the property can take. Also, object properties can have different characteristics

[1] http://en.wikipedia.org/wiki/Ontology_(information_science)

such as functional (can have only one value), inverse (to some other property), sub-property (of another property), or equivalent (to some other property).

In the following sub-sections we will detail the DIET4Elders Nutrition Care Process Ontology defined and used to capture the knowledge about older adult nutrition. Section 3.1 details the ontology design by identifying the main concepts from the modelled domain and classifying them in taxonomies. Section 3.2 details the Protégé[2] implementation of the Nutrition Care Process Ontology.

3.1 Ontology Design

Chapter 2 presented the nutrition related knowledge that is captured by means of ontology in the Nutrition Care Process Ontology, which is composed from four main sub-ontologies (see Figure 6 below):

- Nutrition Monitoring Ontology (the Older Adult Daily Life Context Model from the DIET4Elders project proposal);
- Nutrition Assessment Ontology;
- Nutrition Problem Identification Ontology;
- Nutrition Intervention Ontology (nutrition prescription, dietary constraints, food/meal ordering, etc.).

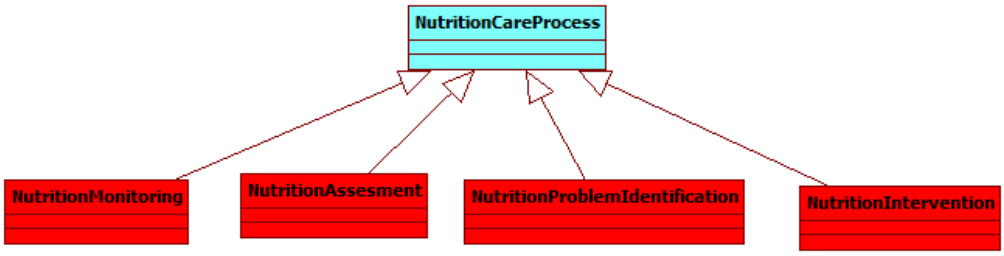


Figure 6: Nutrition Care Process Ontological Core

3.1.1 Nutrition Monitoring Ontology

The objective of the Nutrition Monitoring Ontology is to define and semantically represent all the information that can be on-line or off-line collected regarding the older

[2] http://protege.stanford.edu/

adult, information that is relevant for assessing their nutrition and self-feeding behavior. Nutrition monitoring ontology will store knowledge regarding (see Figure 7):

- **Personal Data** (older adult profile offering information regarding age, sex, location, etc.)
- **Anthropometric Measurements** (e.g. height, weight, weight change, BMI, etc.)
- **Biochemical Data** (information determined through blood analysis)
- **Food Intake** (i.e. older adult food intake over a period of time)
- **Physical Activity**
- **Diet related behavior** (e.g. older adult adherence to or avoidance of a nutritionist prescribed diet)
- **Health profile** (information regarding older adult diseases, allergies or current treatments)
- **Preferences** (food preferences)
- **Beliefs & attitudes** (e.g. vegetarian, doesn't eat meat, etc.)
- **ICT Platform** (e.g. IT services to which the older adult had subscribed; deployed monitored infrastructure and sensors, interaction devices, etc.)

3.1.2 Nutrition Assessment Ontology

The objective of the nutrition assessment ontology is to semantically represent food and nutritional information and to enact the assessment of older adult food intake and associated nutritional values.

Nutrition assessment ontology will store knowledge regarding (see Figure 8):

- **Food Intake** (the food eaten by the older adult during a period of time)

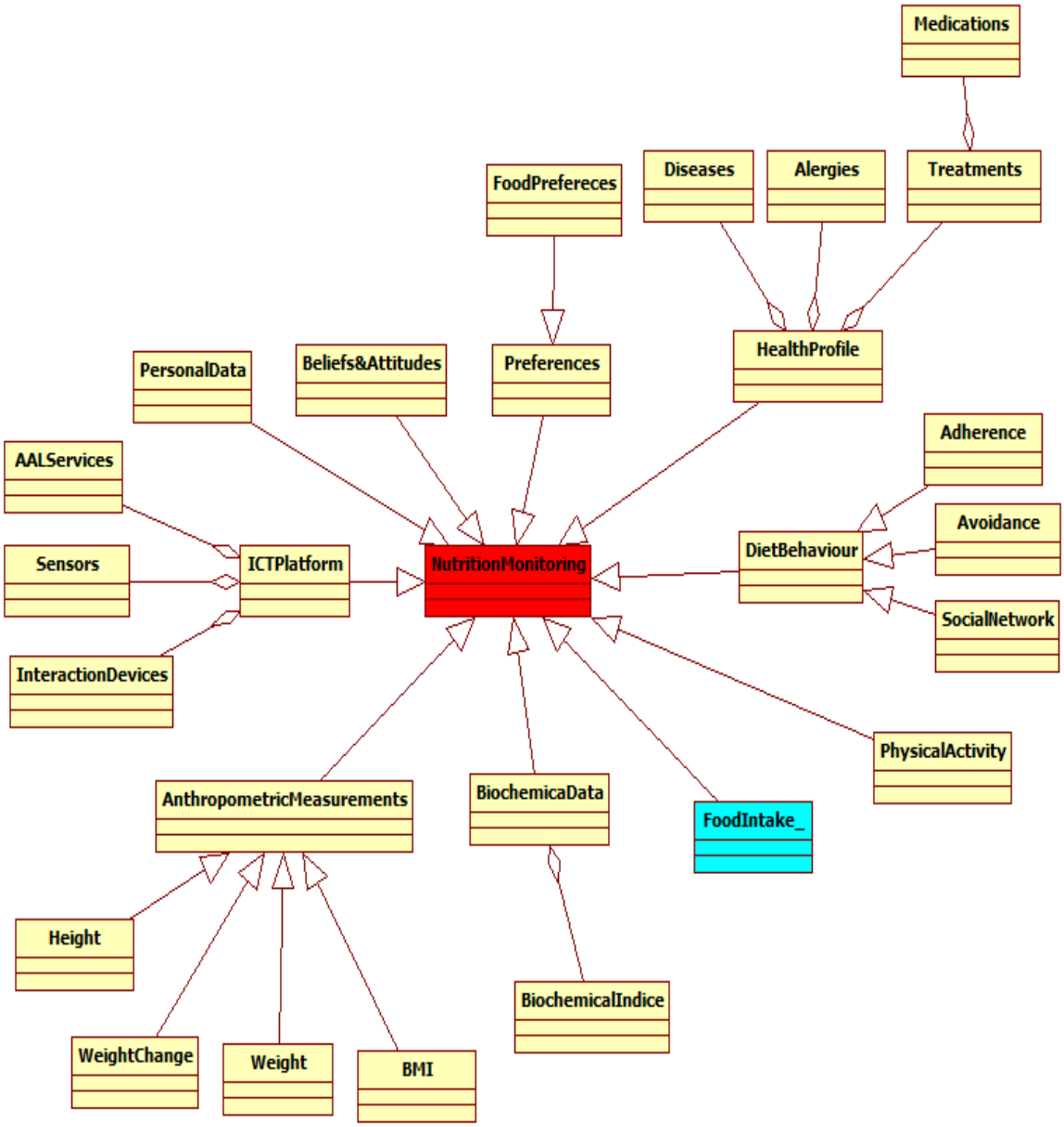


Figure 7: The Nutrition Monitoring Ontology design

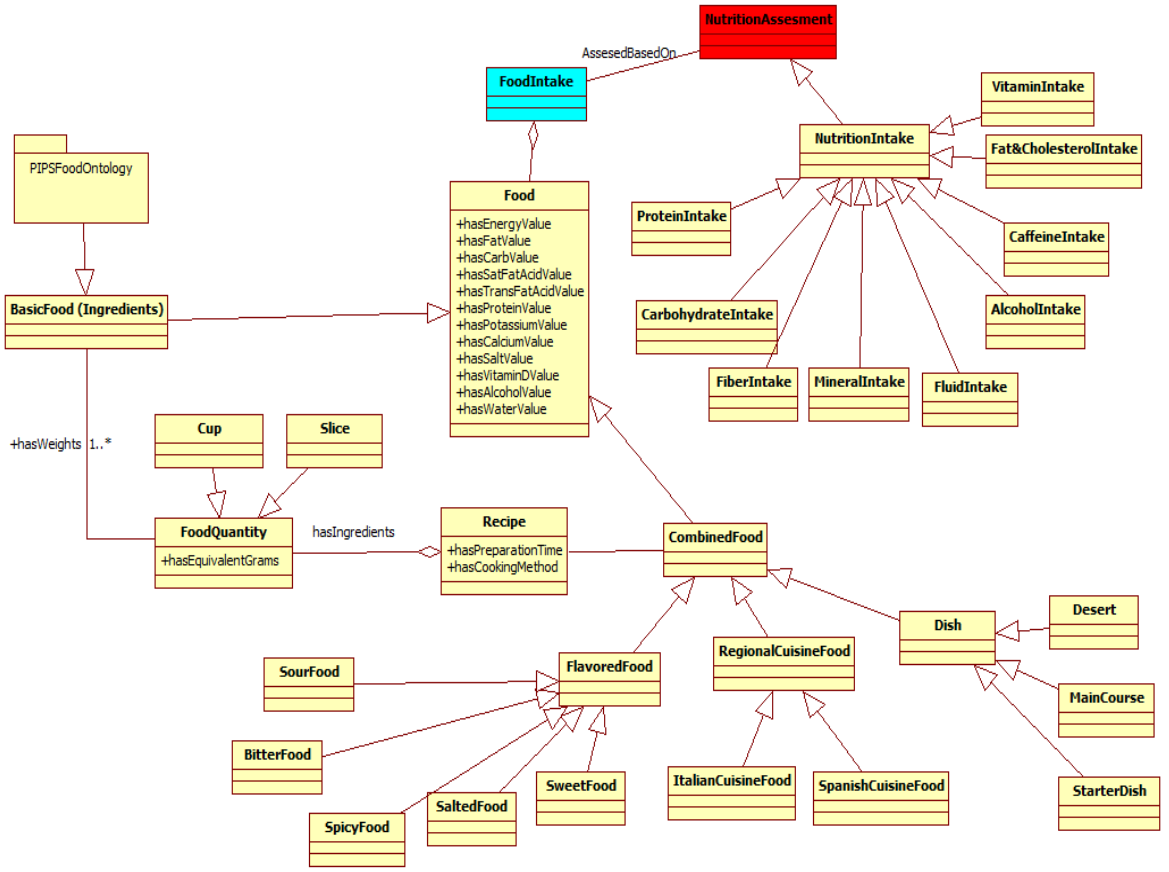


Figure 8: The Nutrition Assessment Ontology

- **Food (**concept describing the generic concept of food**)**
  - **Basic Food** (PIPS Food Ontology based on the Eurocode classification and specification)
  - **Combined Food** (prepared food based on a recipe having as ingredients Basic Food items)
    - **Flavored Food** (e.g. spicy, sour, salted, etc.)
    - **Regional Cuisine Food** (e.g. Italian cuisine, etc.)
    - **Dish** (e.g. desert, main course, etc.)
  - **Recipe** (the recipe based on which a meal is prepared)
  - **Food Quantity** (conversion from volume metric in weight metric)
- **Nutrition Intake** (nutritional values associated with the food intake)
  - Protein, carbohydrate, fiber, mineral, etc.

The ontology will store data about different types of foods and their associated nutritional values. There are two different types of foods: basic food and combined food.

The *basic food* is classified according to the PIPS (Personalized Information Platform for Health and Life Services) food ontology [11] (see Figure 9). PIPS ontology constructs the food taxonomy using the Eurocode food coding. There will be different types of foods such as: beverages, egg products, fruits, grain products, meat, milk products, nuts and seeds, oils and fats, sea food, soups and sauces, special nutrition products, sugar products and vegetables. Each of these types contains subtypes.

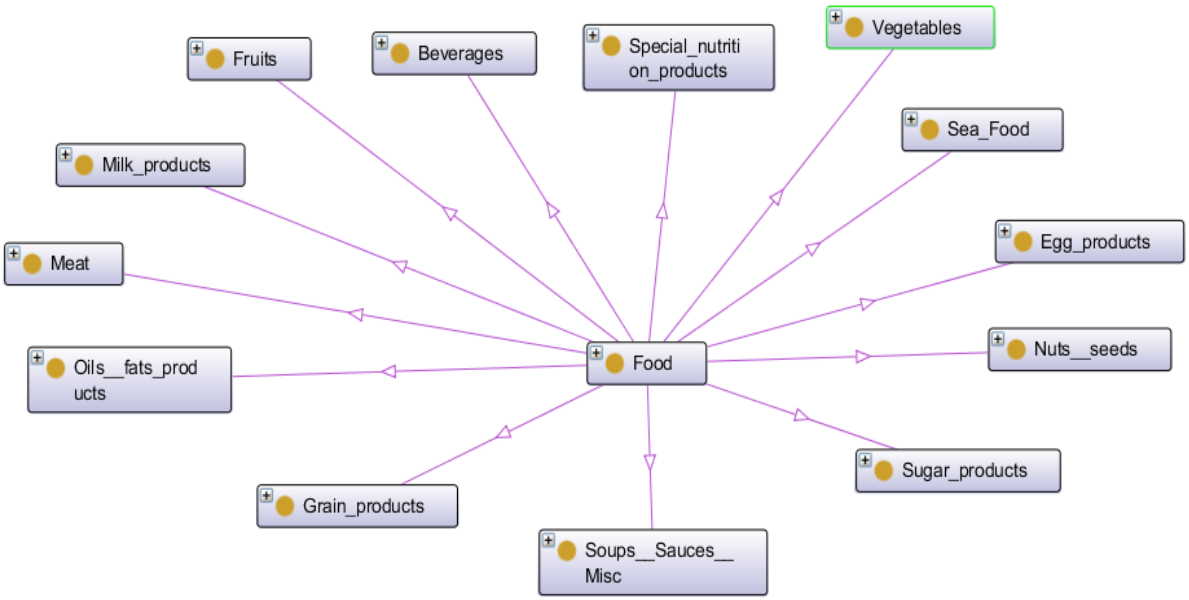


Figure 9: Main taxonomy of PIPS food ontology

The *combined foods* are prepared foods which are based on a recipe of basic food or ingredients. The recipe concept represents a collection of basic foods in different proportions and each recipe will be associated with a combined food. There will be different types of combined foods: flavoured food, regional cuisine food and dish, and each of them will have different subtypes. For example, flavoured food will have the following subtypes: sour food, bitter food, spicy food, salted food and sweet food. Regional cuisine food will be of two types: Italian cuisine food and Spanish cuisine food. Finally, there will be three types of dish: desert, main course, and starter dish.

Another important part of this ontology is represented by the food quantities. There will be different types of food quantities such as slice, cup, bowl, dish, pound, piece, can, box, bag, carton, jar and loaf. Each food will have different values for each of these quantity types.

Nutrition intake will be evaluated each day and it will contain the amounts of nutritional values the older adult consumes during the day such as: energy (kcal), fat (g), carbohydrates (g), fatty acids (g), protein (g), potassium (mg), calcium (mg), sodium (mg), vitamin D (ug), alcohol (g), and water (g). These values are very important because malnutrition is prevented by maintaining nutrient intakes within recommended ranges.

The nutritional values for each specific type of food are taken from the McCance and Widdowson's tables [12] for composing the dishes to provide a wide range of nutrients (e.g. vitamins, fiber, fatty acids, etc.) for the selected food. Details on how the ontology is populated with specific instance from those tables in an automatic manner are provided in sub-section 3.2.2 Ontology Individuals.

3.1.3 Nutrition Problem Identification Ontology

The objective of this ontology is to define, classify and semantically represent potential nutrition related problems and the associated symptoms. Based on the nutrition assessment and nutrition monitoring values this ontology will enact the nutritionist with the possibility of proactive detection of nutrition problems at older adult thus being able to define nutrition intervention schemes that will allow problem prevention before its actual instauration.

Nutrition Problem Identification Ontology represents the following type of nutrition related problems (see Figure 10):

- **Weight based Problem** (e.g. Obesity, unintended weight loss, etc.)
- **Activity based Problem** (e.g. Physical Inactivity, Self-feeding Difficulty, etc.)
- **Malnutrition**
- **Energy Balance Problem** (e.g. excessive or sub-optimal energy intake, etc.)
- **Fluid Intake Problem** (e.g. excessive or sub-optimal fluid intake)

- **Imbalance of Nutrients Problem**

Using the taxonomy of concepts described by this ontology, reasoning rules will be written with the help of nutritionist to proactively detect the early symptoms of nutrition problem instauration at older adults.

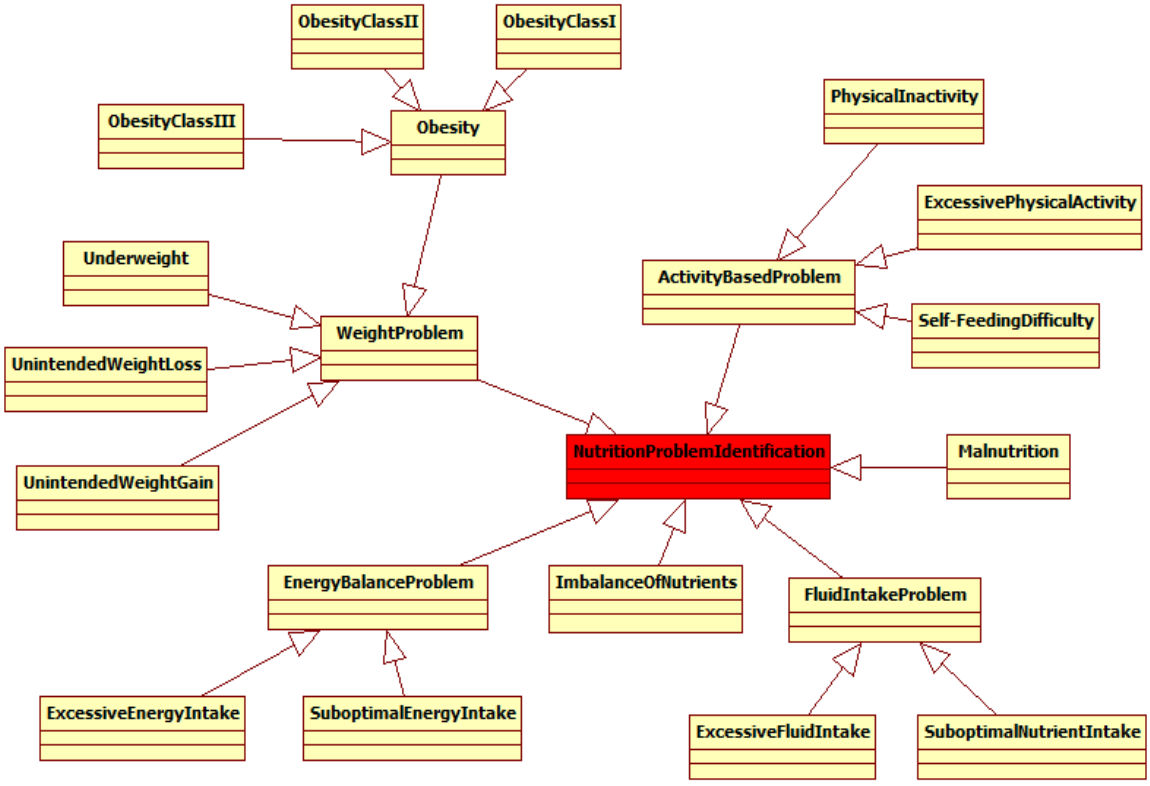


Figure 10: Nutrition Problem Identification Ontology design

3.1.4 Nutrition Intervention Ontology

The Nutrition Intervention Ontology models knowledge and information regarding the type of actions that may be taken in case a nutrition problem or unhealthy behavior is identified for an older adult. Three types of actions are considered and modeled in our ontology (see Figure 11):

- Prescription of a new diet – this is done by a nutritionist and will describe nutrition related constraints that need to be followed by the older adult. The

prescription will be defined in close correlation with the assessed nutrition related behavior or problem identified and nutrition monitored information;

- Food Ordering – the DIET4Elders Food Ordering Service will suggest/order food that complies with the nutritionist prescription and nutrition monitored information. It may order Menus (for example a menu for the whole next week of for the whole day) or a simply meal (Breakfast, Dinner or Lunch);
- Nutrition Education – briefly educate the older adult to eat healthier by building or reinforcing basic nutrition or diet related knowledge.

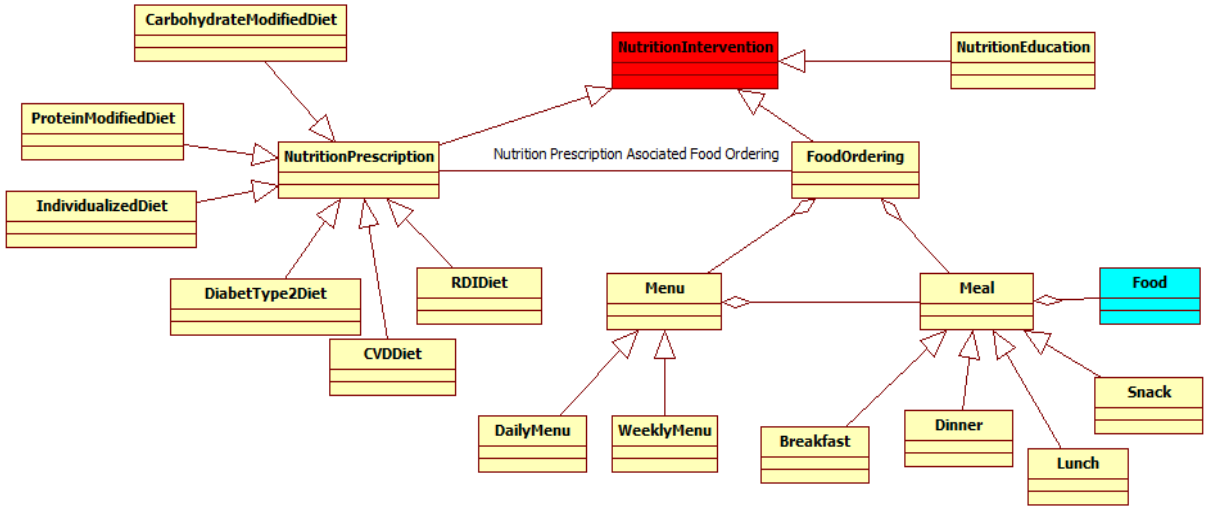


Figure 11: Nutrition Intervention Ontology design

3.2 Ontology Implementation

In this section, details are presented about the implementation of the Nutrition Care Process Ontology. Sub-section 3.2.1 details how the ontological entity concepts are implemented as well as how the object properties and data properties are defined using Protégé[3]. The automatic generation of ontological concepts' individuals by mapping the ontology onto a database will be detailed in sub-section 3.2.2.

[3] http://protege.stanford.edu/

3.2.1 Ontology Concepts, Data and Object Properties

The Nutrition Care Process Ontology implementation is done using the Protégé tool and the Ontology Web Language (OWL)[4]. Figure 12 presents the core ontology concepts implementation using Protégé.

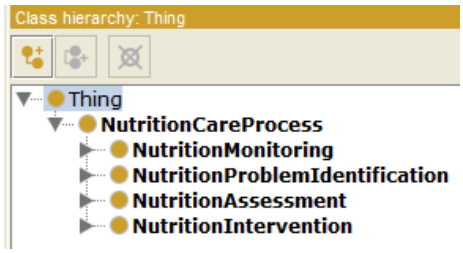


Figure 12: Ontology core concepts in Protégé

Each sub-ontology (of the core ontology) is implemented in separate OWL file. There will be six OWL files which are presented below:

- nutritionmonitoring.owl – nutrition monitoring sub-ontology;
- nutritionassessment.owl – nutrition assessment sub-ontology;
    - food.owl – PIPS food ontology which will be part of the nutrition assessment ontology;
- nutritionproblem.owl – nutrition problem identification sub-ontology;
- nutritionintervention.owl – nutrition intervention sub-ontology;
- nutritioncareprocess.owl – core ontology importing all the above defined sub-ontologies.

Ontologies imports must be handled in Protégé. There are two types of imports: indirect imports and direct imports.

Indirect imports are done automatically (for example the food ontology is already specified using a direct import in the nutrition assessment ontology) while a direct import which points to another ontology need to be specified using configuration files.

The *Protégé implementation of the nutrition monitoring sub-ontology* can be seen in Figure 13. This ontology contains information that is specific for an older adult and may be

[4] http://www.w3.org/TR/owl2-overview/

different for different persons, such as: anthropometric measurements, biochemical data, food intake, health profile, Mediterranean diet adherence, personal data, and physical activity.

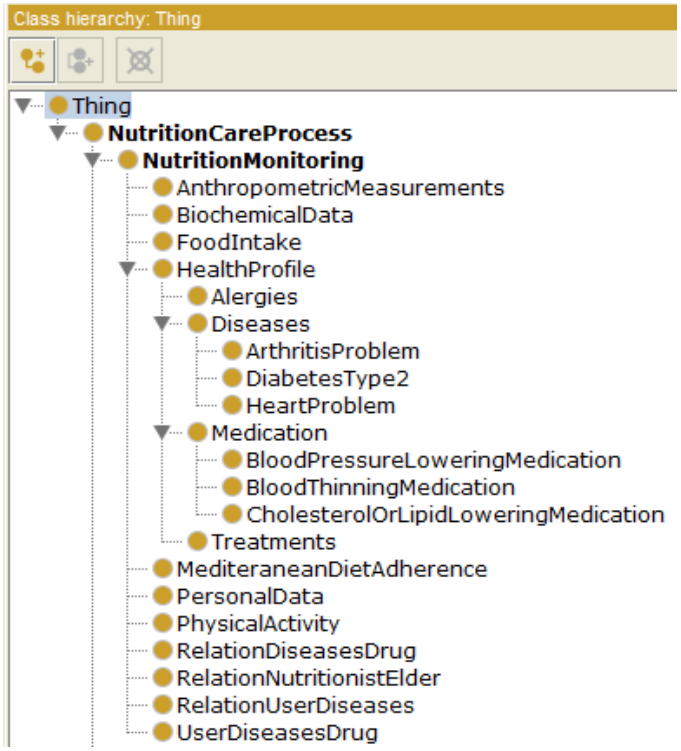


Figure 13: Nutrition monitoring sub-ontology implementation in Protégé

Nutrition assessment sub-ontology implementation in Protégé is depicted in Figure 14. The taxonomy of semantic concepts describes information about foods, food quantities, recipes, and the nutrition intake. Concepts regarding the basic foods are imported from PIPS foods ontology, which contains a hierarchy of foods (classified using Eurocode) such as: beverages, egg products, fruits, grain products, meat, milk products, nuts and seeds, oils and fats products, sea food, soups and sauces, special nutrition products, sugar products and vegetables.

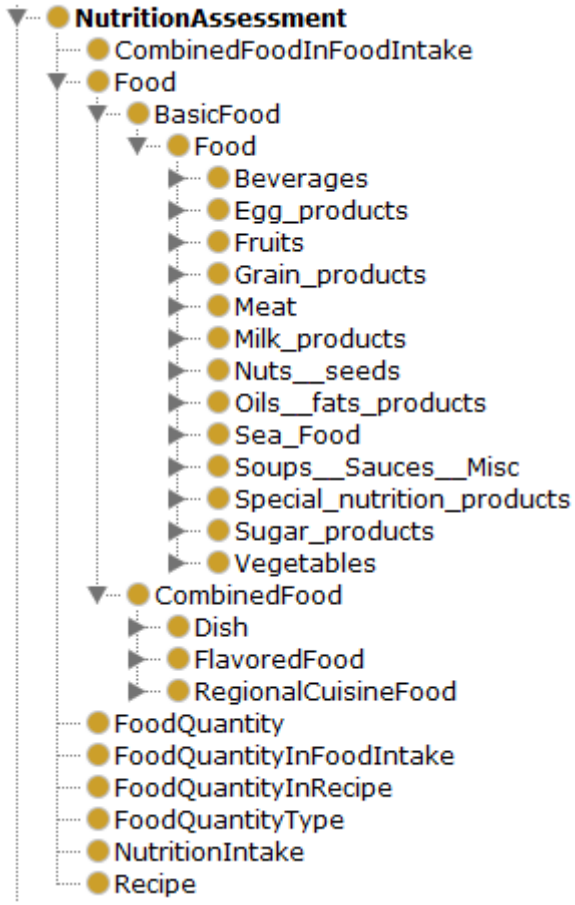


Figure 14: Nutrition Assessment Ontology implementation in Protégé

Nutrition Problem Identification sub-ontology implementation in Protégé is depicted in Figure 15. The implemented concepts describe potential nutrition related problems which may appear to older adults.

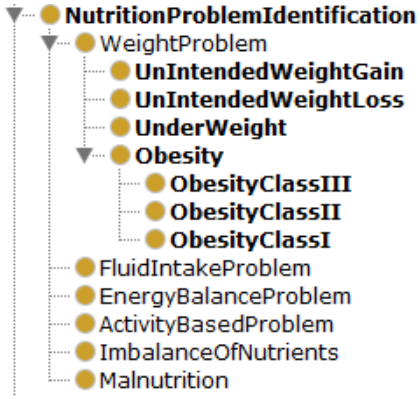


Figure 15: Nutrition Problem Identification Ontology implementation in Protégé

Nutrition Intervention sub-ontology implementationin Protégé is presented in Figure 16. Nutrition intervention ontology contains data about the nutrition prescription, nutrition education and food ordering. The purpose of the nutrition prescription is to suggest the proper diet that the elder should follow knowing that he/she has a certain nutrition related problem.

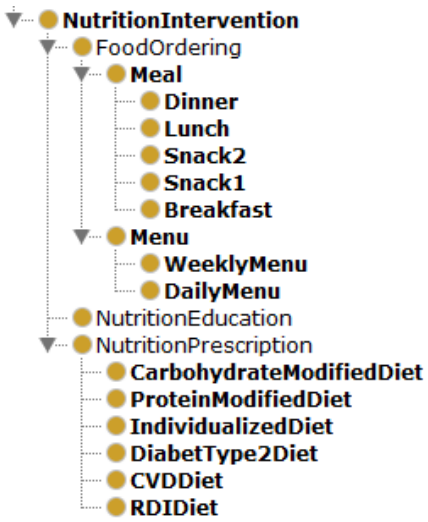


Figure 16: Nutrition Intervention Ontology implementation in Protégé

The relationships among the ontology individuals (the above presented concepts instances) are implemented by means of object properties (see Figure 17). Taking into account the above presented taxonomies of concepts, the object properties are the edges that connect taxonomy nodes.

The eligible data types and value ranges for data values related to the concept instances are implemented by means of datatype properties. We have defined specific datatype properties for all concepts of the Nutrition Care Process Ontology. Figure 18 presents a sub-set of such datatype properties.

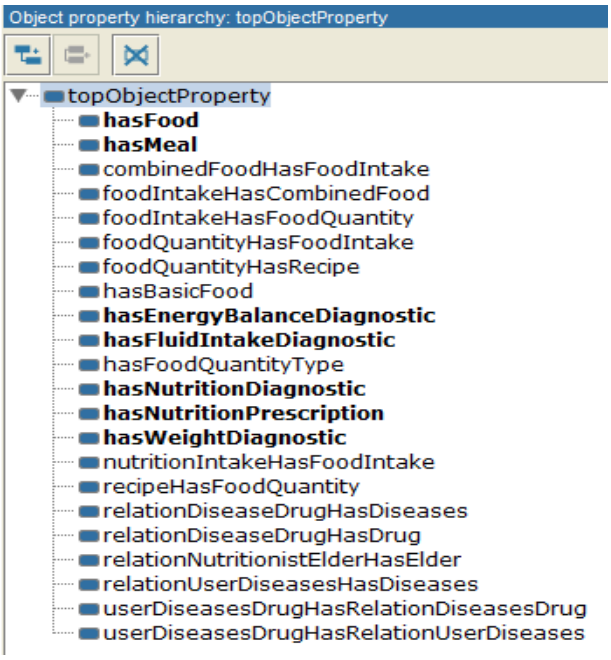


Figure 17: Object properties implemented for the Nutrition Care Process Ontology

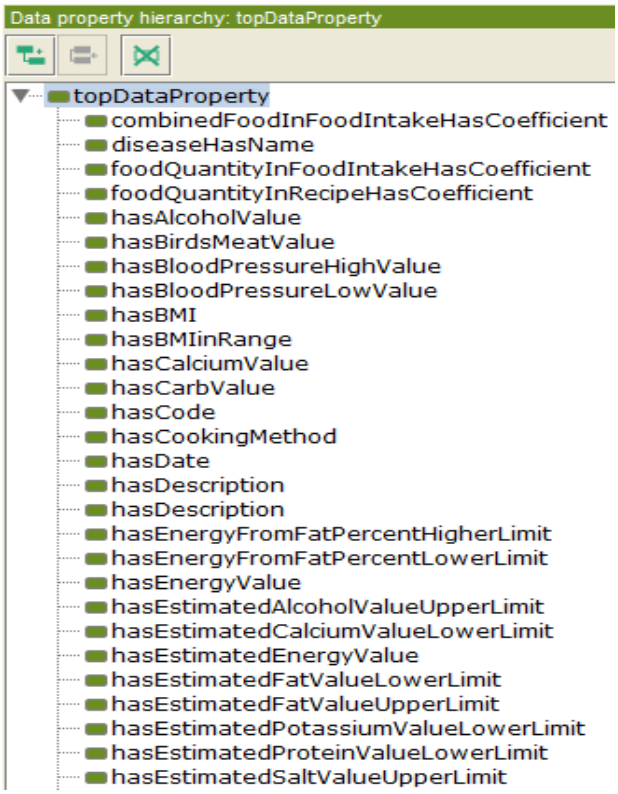


Figure 18: Sub-set of datatype properties implemented for the concepts defined by the Nutrition Care Process Ontology

When defining object or datatype properties, two important concepts are considered: the *Domain*, which represents the set of classes or data types to which the property refers; and the *Range*, which represents the values that the property can take. For example, the fact that a *BasicFood* is associated with a *FoodQuantity* can be expressed as an object property called *hasBasicFood*. The domain of the object property is represented by the class *FoodQuantity*, while the range of the object property is represented by the class *BasicFood*.

3.2.2 Ontology Individuals

Due to the large number of ontology concepts that need to be instantiated and classified in the nutrition care process taxonomy, this process cannot be done manually. Our solution is to store data regarding food items, nutritional information and older adult data (captured by means of questioners and by TUNSTALL ambient monitoring infrastructure) in a relational database and to map the ontology concepts onto the database tables obtaining thus the concept's instances.

The reason for mapping the ontology onto the individuals stored in a database is due to the large quantity of data. The alternative of keeping all data in the nutrition care process ontology has as disadvantage the fact that inserting new data becomes a complex process.

Thus we have defined the following flux of data:

(i) new data is inserted in the database by using SQL insert or update queries;
(ii) creating ontology individuals according to the ontology – database mapping;
(iii) data query from the ontology by using SPARQL[5] queries; and
(iv) inferring new information using SWRL rules[6].

In this sub-section we describe the process of ontology individuals creation by mapping the nutrition care process ontology onto a relational data based while the query and reasoning processes is the subject of Chapter 4.

Two types of data are stored in the relational database tables: food nutritional data and older adult monitored data.

[5] http://www.w3.org/TR/rdf-sparql-query/
[6] http://www.w3.org/Submission/SWRL/

For *food nutritional data* we have used the McCance and Widdowson's tables [12] which provide the description of around 3400 food items. For each food item the main properties are provided such as: the food code (Eurocode format), the food name, description, the number of calories, water, protein, fat, and other nutritional values per 100g.

Three tables from those provided by the McCance tables are important for creating the ontologies instances: inorganics, proximates and vitamins. The three tables contain information relevant for individuals creation such as a list of foods together with their code, name, and description, and they contain also specific information.

Inorganics table contains information such as the quantity of sodium (mg), potassium (mg), calcium (mg), magnesium (mg), phosphorus (mg), iron (mg), copper (mg), zinc (mg), chloride (mg), manganese (mg), selenium (ug), and iodine (ug).

The proximates table contains information about the food that corresponds to 100g such as: water (g), total nitrogen (g), protein (g), fat (g), carbohydrate (g), energy (kcal), energy (kJ), starch (g), oligosaccharide (g), total sugars (g), glucose (g), galactose (g), fructose (g), sucrose (g), maltose (g), lactose (g), alcohol (g), cholesterol (mg), and so on.

The vitamins table contains information about retinol (ug), carotene (ug), retinol equivalent (ug), vitamin D, vitamin E, vitamin K1, thiamin, riboflavin, niacin, vitamin C.

The *older adult monitored data* is acquired by means of the TUNSTALL monitoring infrastructure described in (D2.1) and stored in database tables (see (D4.1) for tables' description).

Different alternatives to connect and map a database to ontology are reported they being studied and compared in the literature [13]. When choosing the solution the following facts should be taken into consideration: how the individuals will be persisted in a database, whether the ontology will be written in a specialized tool, whether a reasoner will be used to infer new knowledge from the already existing data, whether and data will be queried by using a special language such as SPARQL.

After a study of the available solutions, we have chosen to use D2RQ[7] due to the following advantages:

(i) database data can be integrated easily into an ontology;

(ii) classes, object properties and data properties can be managed in the form of database tables;

(iii) there is a clear separation between the ontology data (individuals) and ontology structure; and

(iv) D2RQ can be easily integrated with Jena[8] which is a powerful tool for reasoning on ontologies.

A simplified architecture of how the ontology is mapped to the database using D2RQ and how this mapping can be used in order to get information is presented in Figure 19.

Data about individuals are persisted in a database. A mapping file (*.ttl file) will be used to define the relation between the ontology specific elements (i.e. ontology classes, data properties, object properties, and subclass relations) and the database tables. By using the database and the *.ttl file, D2RQ data will be obtained, which will be populated with the individuals of the ontology (see Figure 19).

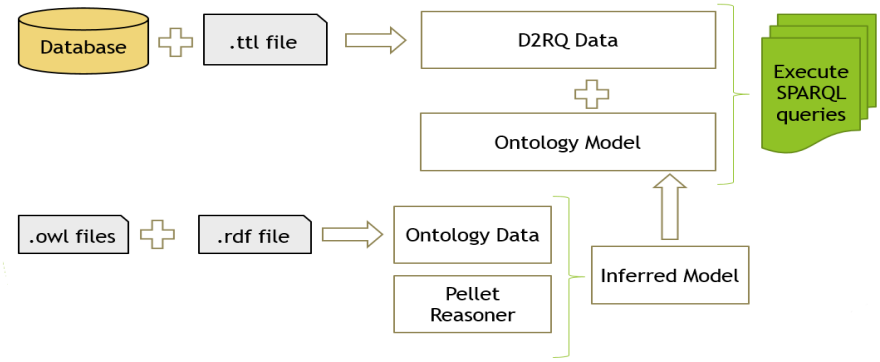


Figure 19: Architecture of mapping ontology to a database

The *.owl files in Figure 19 represent the Nutrition Care Process ontologies described in section 3.2.1. An *.rdf file will handle the ontology imports. By using the

[7] http://d2rq.org/
[8] http://jena.apache.org/documentation/ontology/

*.owl files and the *.rdf file, ontology data will be obtained. The ontologies have associated rules, thus by using the Pellet Reasoner[9], an inferred model is obtained, from which the ontology model is constructed.

After combining the ontology model with the D2RQ data, SPARQL queries can be performed. In our specific case, the *.ttl file will define mapping relations for the following ontology classes:

- Nutrition Assessment Ontology classes
  - Food
  - CombinedFood
  - BasicFood
  - FoodQuantityType
  - FoodIntake
  - FoodQuantityInFoodIntake
  - Recipe
  - FoodQuantityInRecipe
  - CombinedFoodInFoodIntake
  - BasicFoodInFoodIntake
  - NutritionIntake
- Nutrition Monitoring Ontology
  - PersonalData
  - AnthropometricMeasurements
  - BiochemicalData
  - PhysicalActivity
  - Diseases

The first step in defining the mapping of the ontologies onto the database is to declare the namespace of the resources that will be used in the mapping process (see Figure 20). We have defined the namespace of the ontologies involved and other common namespaces that will be used for mapping, such as: rdfs, xsd, jdbc, rdf.

[9] http://clarkparsia.com/pellet/

```
# D2RQ Namespace
@prefix d2rq: <http://www.wiwiss.fu-berlin.de/suhl/bizer/D2RQ/0.1#> .

# Namespace of the ontology
@prefix nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> .
@prefix nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> .
@prefix nutritionproblemidentification:
                <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionproblemidentification#> .
@prefix food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> .

# Namespace of the mapping file; does not appear in mapped data
@prefix map: <#> .

# Other namespaces
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix jdbc: <http://d2rq.org/terms/jdbc/> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
```

Figure 20: Defining namespaces in the mapping file

The next step is to configure the connection to the database that holds the actual data. Figure 21 presents the configuration of this connection using the following parameters: the name of the database, in this case nutritioncareprocess, the name of the jdbc Driver, the username, and the password. Additional properties may be added, like: autoReconnect and zeroDataTimeBehavior.

```
map:database a d2rq:Database;
    d2rq:jdbcDSN "jdbc:mysql://localhost/nutritioncareprocess";
    d2rq:jdbcDriver "com.mysql.jdbc.Driver";
    d2rq:username "root";
    d2rq:password "admin";
    jdbc:autoReconnect "true";
    jdbc:zeroDateTimeBehavior "convertToNull";
```

Figure 21: Defining the database connection configuration in the mapping file

Figure 22 presents an example of an ontology class that is mapped to the database. In order to connect an ontology class to a database table the following parameters must be specified: the name of the database to which the table belongs, the URI pattern of the ontology class which is composed from the name of the ontology and the code of the food, and the name of the class that is mapped (in this case BasicFood).

```
# Table food_properties
map:food_properties a d2rq:ClassMap;
    d2rq:dataStorage map:database;
    d2rq:uriPattern "http://www.semanticweb.org/DIET4Elders/ontologies/
                     /nutritionassessment#BasicFood@@food_properties.code@@";
    d2rq:class nutritionassessment:BasicFood;
```

Figure 22: Defining the mapping an ontology class to a database table

Figure 23 is an example of how to map a data property. In this case, the following properties must be specified: the class to which the data property belongs, the name of the data property, the column to which the data property is associated and the data type which can have different values: string, integer, Boolean, double, etc.

```
# Data Property Name
map:name a d2rq:PropertyBridge;
    d2rq:belongsToClassMap map:food_properties;
    d2rq:property nutritionassessment:hasName;
    d2rq:column "food_properties.name";
    d2rq:datatype xsd:string;
```

Figure 23: Defining the mapping of a data property

An object property connects two ontology classes. The object property from Figure 24, hasBasicFood, connects the classes FoodQuantity and FoodProperties. The mappings for these two classes must be specified: food_quantity and food_properties. Next, the name of the object property is specified, and finally the way in which the property connects the two tables based on the foreign key relation, (i.e. the code of the food properties is equal with the basic food id of the food quantity).

```
# Object property hasBasicFood
map:hasBasicFood a d2rq:PropertyBridge;
    d2rq:belongsToClassMap map:food_quantity;
    d2rq:property nutritionassessment:hasBasicFood;
    d2rq:refersToClassMap map:food_properties;
    d2rq:join "food_quantity.id = food_quantity_2.id";
    d2rq:join "food_quantity.basic_food_id = food_properties.code";
    d2rq:alias "food_quantity as food_quantity_2";
```

Figure 24: Defining the mapping of an object property

Mapping of a subclass is similar with the mapping of an object property. Figure 25 shows an example of mapping of a subclass. The following things must be specified: the class to which the mapped subclass is a child, the fact that the property defines a type relation, and the column that contains the name of the subclass.

```
# Object property - subclass - FoodSubtype
map:FoodSubtype a d2rq:PropertyBridge;
    d2rq:belongsToClassMap map:food_properties;
    d2rq:property rdf:type;
    d2rq:uriPattern "http://www.semanticweb.org/DIET4Elders/
                     /ontologies/food#@@food_properties.subtype@@";
```

Figure 25: Defining the mapping of a subclass

4. Behaviour Assessment Techniques

Based on the Nutrition Care Process ontology, the goal of this chapter is to present reasoning mechanisms used to identify long term and short term unhealthy older adult behaviour, as well as to identify the potential nutrition associated problems.

4.1 Reasoning Based Infrastructure

Figure 26 shows the architecture of the DIET4Elders reasoning infrastructure based on the ontology instances obtained by mapping the Nutrition Care Process ontologies to the DIET4Elders database as presented in sub-section 3.2.2.

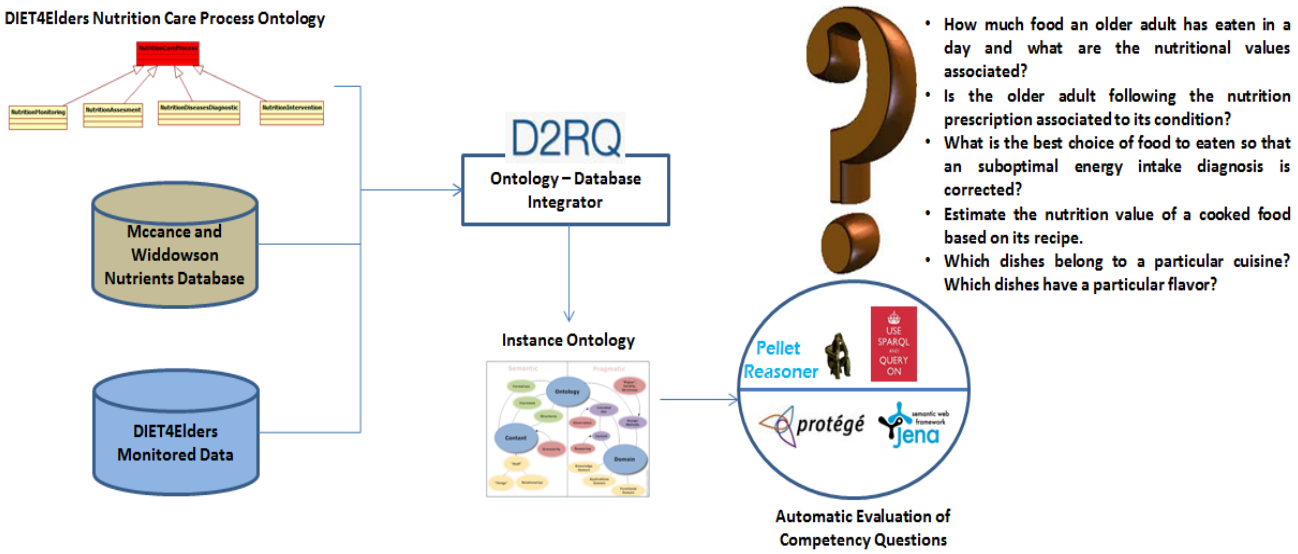


Figure 26: DIET4Elders reasoning infrastructure conceptual architecture

Two types of rules are defined and used on the Nutrition Care Process ontology classes and associated individuals: reasoning rules and query rules.

The *reasoning rules* are written in the SWRL language and used to infer new nutrition related information and/or knowledge out of the ontology. The SWRL rules are injected into the nutrition care process ontology and used to reason about the ontology individuals in terms of specific concepts, object and datatype properties. The rules are written in the form of an implication between an *antecedent* (body) and *consequent* (head).

Both the antecedent and consequent consist of multiple atoms conjunctions. The SWRL rules are evaluated by a reasoning engine, in our case the Pellet reasoner.

The *query rules* are written in SPARQL. The SPARQL language is data-oriented in the sense that it only queries the individuals held in the ontological models and makes no inferences. The queries can return data that exists in the ontology but also new data that is inferred. SPARQL also provides ways to perform some mathematical functions such as sum.

Jena is a framework for ontology management that provides ways to write and read RDF as XML. Jena also provides ways to navigate a model and to get data from it. One way to get data about a resources is to specify the resource's URI and to ask the model to retrieve the resource associated to that URI. Also, there are ways to get the properties that are associated to a resource.

4.2 Assessing Short Term Unhealthy Behavior

To assess the older adult short term unhealthy behaviours, the older adult nutrition process is evaluated against the benchmarks and dietary recommendations for older people defined by nutritionists in Chapter 2.

The nutrition knowledge presented in Table 2 are represented using SWRL reasoning rules (see Table 8) injected in the Nutrition Care Process ontology and evaluated by means of the Pellet reasoning engine. If the conjunctions specified in the SWRL rule antecedent are false for a specific older adult, the rule consequent classifies the corresponding un-healthy behavior.

For example, the first rule in Table 8 evaluates if the older adult's BMI is in the normal range (i.e. greater than 20 and less than 30 as defined by nutritionists). In the defined Nutrition Care Process Ontology, each older adult is associated with a set of anthropometric measurements, including height, weight and weight change. Also in this ontology, we have defined a concept BMI, which has a dataType property '*hasBMIinRange'* that can be set to true if the value is in the required range and to false otherwise. The defined SWRL rule is evaluated on the ontology in the following way: in the antecedent part of the rule the set of anthropometric measurements (referred to as ?x)

are selected to determine the value of the BMI (referred to as ?y) using the '*hasBMI'* objectType property. To evaluate that the determined value is in range the '*lessThanOrEqual' and 'greaterThanOrEqual'* SWRL operators are used. The result of the antecedent evaluation (true or false) is attributed in the consequent to the '*hasBMIinRange'* property.

Table 8: SWRL rules for detecting older adult short term nutrition related un-healthy behaviours

Evaluation Criteria	**Nutrition Behavior Assessment Rule**	**SWRL Rule Implementation**
BMI	~ 20-30 kg/m2	*AnthropometricMeasurements(?x), hasBMI(?x, ?y), greaterThanOrEqual(?y, 20.0), lessThanOrEqual(?y, 30.0) -> hasBMIinRange(?x, true)*
Energy	Men: ~ 9.8 MJ/day Women: ~ 8.0 MJ/day	*AnthropometricMeasurements(?z), FoodIntake(?x), PersonalData(?p), PhysicalActivity(?ph), hasGender(?p, "female"^^string), hasHeight(?z, ?h), hasPAF(?ph, ?f), hasUsername(?p, ?n), hasUsername(?ph, ?n), hasUsername(?x, ?n), hasUsername(?z, ?n), hasWeight(?z, ?w), add(?s1, ?r1, ?r2), add(?s2, ?s1, 0.0448), multiply(?m1, ?s2, ?f), multiply(?r1, ?w, 0.0356), multiply(?r2, ?h, 0.0176), multiply(?rez, ?m1, 239) -> hasEstimatedEnergyValue(?x, ?rez)*
Total fat	~ 20-35% energy	*FoodIntake(?x), hasEstimatedEnergyValue(?x, ?e), divide(?r, ?m, 100.0), divide(?rez, ?r, 9.0), multiply(?m, ?e, 35.0) -> hasEstimatedFatValueUpperLimit(?x, ?rez)* *FoodIntake(?x), hasEstimatedEnergyValue(?x, ?e), divide(?r, ?m, 100.0), divide(?rez, ?r, 9.0), multiply(?m, ?e, 20.0) -> hasEstimatedFatValueLowerLimit(?x, ?rez)*
Saturated fatty acids	< 11% energy	*FoodIntake(?x), hasEstimatedEnergyValue(?x, ?e), divide(?r, ?m, 100.0), divide(?rez, ?r, 9.0), multiply(?m, ?e, 11.0) -> hasEstimatedSatFatAcidValueUpperLimit(?x, ?rez)*
Trans fatty acids	< 1% energy	*FoodIntake(?x), hasEstimatedEnergyValue(?x, ?e), divide(?r, ?m, 100.0), divide(?rez, ?r, 9.0), multiply(?m, ?e, 1.0) -> hasEstimatedTransFatAcidValueUpperLimit(?x, ?rez)*
Protein	> 0.75g/kg body weight / day	*AnthropometricMeasurements(?z), FoodIntake(?x), hasUsername(?x, ?n), hasUsername(?z, ?n), hasWeight(?z, ?w), multiply(?r, ?w, 0.75) -> hasEstimatedProteinValueLowerLimit(?x, ?r)*
Potassium	> 3.5g/d	*FoodIntake(?x) -> hasEstimatedPotassiumValueLowerLimit(?x, 3.5)*
Calcium	> 700 mg/ day	*FoodIntake(?x) -> hasEstimatedCalciumValueLowerLimit(?x, 700.0)*
Vitamin D	~10 micrograms/day	*FoodIntake(?x) -> hasEstimatedVitaminDValue(?x, 10.0)*
Salt	< 6 g / day	*FoodIntake(?x) -> hasEstimatedSaltValueUpperLimit(?x, 6.0)*
Alcohol	Men: < 28 units / week Women: < 21 units/	*FoodIntake(?x), PersonalData(?p), hasGender(?p, "male"^^string), hasUsername(?p, ?u), hasUsername(?x, ?u) -> hasEstimatedAlcoholValueUpperLimit(?x, 224.0)*

	week	
Fluid	Men: ~ 2.5 L / day Women: ~ 2L / day	*FoodIntake(?x), PersonalData(?p), hasGender(?p, "male"^^string), hasUsername(?p, ?u), hasUsername(?x, ?u) -> hasEstimatedWaterValue(?x, 2500.0)*

Also, using the Diet4Elders Automated Nutrition Problems described in sub-section 2.3.3, we have implemented the reasoning rules to proactively detect the early instauration of specific nutrition related problems to older adults. Table 9 shows the SWRL implementation for each older adult nutrition related problem as defined by nutritionists in Table 4.

For example, to detect the nutrition problem related to inadequate fluid intake, the third SWRL rule from Table 9 is used. Each older adult consumes different amounts of food and drinks during the day, which are stored in the Nutrition Care Process Ontology. Using the McCance and Widdowson's tables, the nutritional values associated with the older adult's intake are computed (i.e. how many proteins, how many carbohydrates, how much liquids, and so on). In the case of inadequate fluid intake, the reasoning works as follows: given a nutrition intake, which is substituted by *?i*, the value of the water consumed, which is called *?w, is determined.* If this value, *?w*, is less than or equal to 1.5, the nutrition intake will be associated with a fluid intake problem corresponding to the fact that the fluid intake is suboptimal.

Table 9: Implementing the SWRL for detecting the early instauration on nutrition related problems

Nutrition related Problem	**SWRL Rule Implementation**
Predicted sub-optimal energy intake	*AnthropometricMeasurements(?a), hasWeightChange(?a, ?w), lessThanOrEqual(?w, -3.0) -> hasNutritionProblem(?a, SuboptimalEnergyIntake)*
Predicted excessive energy intake	*AnthropometricMeasurements(?a), hasWeightChange(?a, ?w), greaterThanOrEqual(?w, 3.0) -> hasNutritionProblem(?a, ExcessiveEnergyIntake)*
Inadequate fluid intake	*NutritionIntake(?i), nutritionIntakeHasWaterValue(?i, ?w), lessThanOrEqual(?w, 1.5) -> hasFluidIntakeProblem(?i, SuboptimalFluidIntake)*
Less than optimal intake of types of fat	*NutritionIntake(?i), nutritionIntakeHasFatValue(?i, ?v), nutritionIntakeHasSatFatAcidValue(?i, ?s), multiply(?result, ?v, 0.11), greaterThan(?s, ?result) -> hasNutritionProblem(?a, SuboptimalFatIntake)*
Underweight	*AnthropometricMeasurements(?a), hasBMI(?a, ?bmi), lessThan(?bmi, 18.5) -> hasWeightProblem(?a, Underweight)*

Overweight	*AnthropometricMeasurements(?a), hasBMI(?a, ?bmi), greaterThanOrEqual(?bmi, 25.0), lessThan (?bmi, 30.0) -> hasWeightProblem(?a, Overweight)*
Obesity	*AnthropometricMeasurements(?a), hasBMI(?a, ?bmi), greaterThanOrEqual(?bmi, 30.0) -> hasWeightProblem(?a, Obesity)*
Diabetes type 2	*Diseases(?y), PersonalData(?x), diseaseHasName(?y, "Diabetes Type 2"^^string), hasUsername(?x, ?n), hasUsername(?y, ?n) -> hasNutritionPrescription(?x, DiabetType2Diet)*
Cardio vascular disease	*Diseases(?y), PersonalData(?x), diseaseHasName(?y, "Cardio Vascular Disease"^^string), hasUsername(?x, ?n), hasUsername(?y, ?n) -> hasNutritionPrescription(?x, CVDDiet)*

4.3 Assessing Long Term Unhealthy Behaviour

For older adult long term dietary assessment, the Mediterranean Diet Adherence Score presented in Table 1 is used. This approach allows an assessment of dietary quality using 14-item evaluation criteria. Table 10 shows how the SPARQL rules defined and used for evaluating the older adult the adherence score to the Mediterranean diet.

As an example of how SPARQL works, consider the query that asks how many vegetable servings one consumes per day (Question 3 in Table 10). The query starts with the declaration of prefixes which are of two types: (i) standard prefixes: xsd and rdf; and (ii) prefixes from the Nutrition Care Process Ontology: food, nutritionassessment and nutritionmonitoring. The query retrieves the food intake and the quantity of vegetables consumed during a day for an older adult. First, the food intake is determined by searching the food ontology. For each type of food intake that is of type *Vegetables* in this ontology, the *'foodQuantitiesInFoodIntake'* dataProperty is considered. The sum of these data values is the overall quantity of vegetables consumed during the day.

Table 10: Implementing the SPARQL rules for evaluating Mediterranean Diet Adherence Score

Questions	SPARQL rules implementation
1. Do you use olive oil as main culinary fat? 2. How much olive oil do you consume in a given day (including oil used for frying, salads, out-of-house meals, etc)?	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> " + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> " + "SELECT ?foodIntake (SUM(xsd:double(?coefficient) * xsd:double(?grams)) AS ?Grams) " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate \"" + dateString + "\"^^xsd:dateTime . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake . " + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuantity . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityInFoodIntakeHasCoefficient ?coefficie + " ?foodQuantity nutritionassessment:hasGramsValue ?grams . " + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " ?basicFood nutritionassessment:hasName \"Olive oil\" . " + " } GROUP BY ?foodIntake ";
3. How many vegetable servings do you consume per day (1 serving: 200g; consider side dishes as half a serving)	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> " + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> " + "SELECT ?foodIntake (SUM(xsd:double(?coefficient) * xsd:double(?grams)) AS ?Grams) " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate \"" + dateString + "\"^^xsd:dateTime . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake . " + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuantity . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityInFoodIntakeHasCoefficient ?coefficie + " ?foodQuantity nutritionassessment:hasGramsValue ?grams . " + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " ?basicFood rdf:type food:Vegetables . " + " } GROUP BY ?foodIntake ";
4. How many fruit units (including natural fruit juices) do you consume per day?	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> + "SELECT DISTINCT ?foodIntake ?foodQuantityInFoodIntake " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate \"" + dateString + "\"^^xsd:dateTime . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuanti + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " { ?basicFood rdf:type food:Fruits } " + " UNION " + " { ?basicFood rdf:type food:Fruit_juices } " + " } ";

Questions	SPARQL rules implementation
5. How many servings of red meat, hamburger, or meat products (ham, etc) do you consume per day (1 serving: 100 – 150g).	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> " + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> " + "SELECT ?foodIntake (SUM(xsd:double(?coefficient) * xsd:double(?grams)) AS ?Grams) " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate \"" + dateString + "\"^^xsd:dateTime . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake . " + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuantity . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityInFoodIntakeHasCoefficient ?coefficie + " ?foodQuantity nutritionassessment:hasGramsValue ?grams . " + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " {?basicFood rdf:type food:Meat_products } " + " UNION " + " {?basicFood rdf:type food:Beef__carcass_meat }" + " } GROUP BY ?foodIntake ";
6. How many servings of butter, margarine or cream do you consumer per day (1 serving: 12 g)	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> " + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> " + "SELECT ?foodIntake (SUM(xsd:double(?coefficient) * xsd:double(?grams)) AS ?Grams) " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate \"" + dateString + "\"^^xsd:dateTime . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake . " + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuantity . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityInFoodIntakeHasCoefficient ?coefficie + " ?foodQuantity nutritionassessment:hasGramsValue ?grams . " + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " {?basicFood rdf:type food:Margarine } " + " UNION " + " {?basicFood rdf:type food:Butter }" + " } GROUP BY ?foodIntake ";
7. How many sweet or carbonated beverages do you drink per day?	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> + "SELECT DISTINCT ?foodIntake ?foodQuantityInFoodIntake " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate \"" + dateString + "\"^^xsd:dateTime . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuanti + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " ?basicFood rdf:type food:Carbonated_soft_drinks " + " } ";

Questions	SPARQL rules implementation
8. How much wine do you drink per week?	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> + "SELECT DISTINCT ?foodIntake ?foodQuantityInFoodIntake " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate ?date " + " FILTER(xsd:dateTime(?date) >= \"" + startString + "\"^^xsd:dateTime && " + " xsd:dateTime(?date) <= \"" + endString + "\"^^xsd:dateTime) " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuanti + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " ?basicFood rdf:type food:Wines " + " } ";
9. How many servings of legumes do you consume per week? (1 serving: 150g)	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> " + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> " + "SELECT ?foodIntake (SUM(xsd:double(?coefficient) * xsd:double(?grams)) AS ?Grams) " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate ?date " + " FILTER(xsd:dateTime(?date) >= \"" + startString + "\"^^xsd:dateTime && " + " xsd:dateTime(?date) <= \"" + endString + "\"^^xsd:dateTime) " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake . " + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuantity . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityInFoodIntakeHasCoefficient ?coefficie + " ?foodQuantity nutritionassessment:hasGramsValue ?grams . " + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " ?basicFood rdf:type food:Vegetables . " + " } GROUP BY ?foodIntake ";

Questions	SPARQL rules implementation
10. How many servings of fish or shellfish do you consume per week? (1 serving 100-150g fish or 4-5 units or 200g of shellfish)	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> " + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> " + "SELECT ?foodIntake (SUM(xsd:double(?coefficient) * xsd:double(?grams)) AS ?Grams) " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate ?date " + " FILTER(xsd:dateTime(?date) >= \"" + startString + "\"^^xsd:dateTime && " + " xsd:dateTime(?date) <= \"" + endString + "\"^^xsd:dateTime) " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake . " + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuantity . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityInFoodIntakeHasCoefficient ?coefficie + " ?foodQuantity nutritionassessment:hasGramsValue ?grams . " + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " { ?basicFood rdf:type food:Smoked_fish } " + " UNION " + " { ?basicFood rdf:type food:Other_fish } " + " UNION " + " { ?basicFood rdf:type food:Pickled_fish } " + " UNION " + " { ?basicFood rdf:type food:Dried_and_salted_fish } " + " UNION " + " { ?basicFood rdf:type food:Fish_products } " + " UNION " + " { ?basicFood rdf:type food:Canned_fish } " + " UNION " + " { ?basicFood rdf:type food:Restructured_fish_and_fish_analogues } " + " } GROUP BY ?foodIntake ";
11. How many times per week do you consume commercial sweets or pastries, such as cakes, cookies, biscuits, or custard?	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> + "SELECT DISTINCT ?foodIntake ?date " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate ?date " + " FILTER(xsd:dateTime(?date) >= \"" + startString + "\"^^xsd:dateTime && " + " xsd:dateTime(?date) <= \"" + endString + "\"^^xsd:dateTime) " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuanti + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " ?basicFood rdf:type food:Sugar_products " + " } ";

Questions	SPARQL rules implementation
12. How many servings of nuts (including peanuts) do you consume per week? (1 serving 30g)	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> " + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> " + "SELECT ?foodIntake (SUM(xsd:double(?coefficient) * xsd:double(?grams)) AS ?Grams) " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate ?date " + " FILTER(xsd:dateTime(?date) >= \"" + startString + "\"^^xsd:dateTime && " + " xsd:dateTime(?date) <= \"" + endString + "\"^^xsd:dateTime) " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake . " + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuantity . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityInFoodIntakeHasCoefficient ?coefficie + " ?foodQuantity nutritionassessment:hasGramsValue ?grams . " + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " ?basicFood rdf:type food:Nuts__seeds " + " } GROUP BY ?foodIntake ";
13. Do you preferentially consume chicken, turkey, or rabbit meat instead of veal, pork, hamburger or sausage?	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> " + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> " + "SELECT ?foodIntake (SUM(xsd:double(?coefficient) * xsd:double(?grams)) AS ?Grams) " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate ?date " + " FILTER(xsd:dateTime(?date) >= \"" + startString + "\"^^xsd:dateTime && " + " xsd:dateTime(?date) <= \"" + endString + "\"^^xsd:dateTime) " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake . " + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuantity . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityInFoodIntakeHasCoefficient ?coefficie + " ?foodQuantity nutritionassessment:hasGramsValue ?grams . " + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " { ?basicFood rdf:type food:Chicken } " + " UNION " + " { ?basicFood rdf:type food:Turkey } " + " UNION " + " { ?basicFood rdf:type food:Birds__other }" + " } GROUP BY ?foodIntake "; "PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> " + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> " + "SELECT ?foodIntake (SUM(xsd:double(?coefficient) * xsd:double(?grams)) AS ?Grams) " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate ?date " + " FILTER(xsd:dateTime(?date) >= \"" + startString + "\"^^xsd:dateTime && " + " xsd:dateTime(?date) <= \"" + endString + "\"^^xsd:dateTime) " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake . " + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuantity . " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityInFoodIntakeHasCoefficient ?coefficie + " ?foodQuantity nutritionassessment:hasGramsValue ?grams . " + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " { ?basicFood rdf:type food:Veal_carcass_meat } " + " UNION " + " { ?basicFood rdf:type food:Pork__piglet_carcass_meat } " + " } GROUP BY ?foodIntake ";

Questions	SPARQL rules implementation
14. How many times per week do you consume vegetables, pasta, rice, or other dishes seasoned with sofrito?	"PREFIX foods: <http://www.semanticweb.org/foodsontology/food/#> " + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>" + "PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> " + "PREFIX food: <http://www.semanticweb.org/DIET4Elders/ontologies/food#> " + "PREFIX nutritionassessment: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionassessment#> + "PREFIX nutritionmonitoring: <http://www.semanticweb.org/DIET4Elders/ontologies/nutritionmonitoring#> + "SELECT DISTINCT ?foodIntake ?date " + " WHERE {" + " ?foodIntake nutritionmonitoring:hasUsername \"" + username + "\" . " + " ?foodIntake nutritionmonitoring:hasDate ?date " + " FILTER(xsd:dateTime(?date) >= \"" + startString + "\"^^xsd:dateTime && " + " xsd:dateTime(?date) <= \"" + endString + "\"^^xsd:dateTime) " + " ?foodQuantityInFoodIntake nutritionassessment:foodQuantityHasFoodIntake ?foodIntake + " ?foodQuantityInFoodIntake nutritionassessment:foodIntakeHasFoodQuantity ?foodQuanti + " ?foodQuantity nutritionassessment:hasBasicFood ?basicFood . " + " { ?basicFood rdf:type food:Rice_basic_products } " + " UNION " + " { ?basicFood rdf:type food:Pasta_and_noodles }" + " } ";

5. Summary and Future Plan

In this deliverable, we have presented the progress achieved so far for WP3 - *Domain Knowledge Construction, Data Analysis and Self-feeding Behavior Assessment*.

In particular, for Task 3.1 (*Development of Clinically-informed Diet knowledge and Scenarios*), we have investigated the nutrition care process for assessing and managing older adults' diet, providing dietary and nutrient benchmarks based on relevant nutritional knowledge and guidelines, diet selection based on scenarios, nutritional problem detection rules, and nutrition intervention options.

For Task 3.2 (*Domain Knowledge/Ontology Construction and Representation*), and based on the analysis conducted in Task 3.1, we have designed and constructed the Older Adults Nutrition Care Process Ontology, organised into 4 sub-ontologies. The ontology is implemented using the Protégé tool and the Ontology Web Language (OWL), and is populated by mapping it to the DIET4Elders database using D2RQ.

For Task 3.3 (*Development of Techniques for Assessing the Older Adult Self-feeding Behaviour*), we have introduced a reasoning based infrastructure for assessing and evaluating the self-feeding behaviour of older adults. The infrastructure is based on Pellet reasoning engine for evaluating SPARQL and SWRL rules, which describe unhealthy short-term and long-term older adult behaviour, and detect nutrition problems. The evaluation of the reasoning rules is carried out on the Nutrition Care Process Ontology having as underlining data, the older adult's monitored data.

Future work involves refining and improving the models and techniques developed based on evaluation results, as well as working on Task 3.4 (*Development of Techniques for Older Adult's Long-term Dietary Assessment*). Specifically, a provenance infrastructure for the system will be investigated and designed to capture and provide access to the causal connections between different events occurring in the system suitably adapted to provide long-term analysis of the effects of the system on the older adults' diet.

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