D4.2 – First prototype of the DSS

2019.02.28

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Short Abstract

The D4.2 is the software that conforms the first prototype of the Decision Support System. As the DSS is merely designed and implemented in form of a Software as a Service platform, and it does not have any graphical user interface, this document is intended to report a description of the DSS first prototype main features with a particular focus on the architecture, functionalities and technical implementation. Therefore, the aim of this document is to provide a picture of the actual development of the DSS starting from the scientific background from which it is grounded and going through the different elements that form the DSS. The DSS main objective is to help users in selecting coaching plans by proposing personalised recommendations based on users' behaviours and preferences. Recognising such behaviours and their evolution over time is therefore a crucial element for tailoring the interaction of the system with the user. A three-layer system composed of pathways, coaching activity plans, and coaching events, constitutes the so-called coaching timeline on which the analysis is grounded. Various techniques are used to model and personalise the recommendations and feedback. Firstly, the indicators are extracted from disparate data sources, then these are modelled through a profiling system and, finally, recommendations on the pathways and coaching plans are performed through a tagging system. With the aim of developing and testing the models and workflow prior to the pilot starting date, two simulators are also being implemented and reported in this document.

Key Words

Decision Support System; Architecture; Functionalities; Data Processing; Data Sources; Scoring System; Tagging System; Scheduler; Pathway; Coaching Activity Plan; Coaching Event; API Services; Data Simulators.

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1 Introduction

NESTORE deploys several tools towards fostering the adoption of well-being of older people. However, the success of the mechanisms designed throughout the different modules of the project greatly depends on the user engagement with the platform and, more specifically, with the degree of personalisation of those mechanisms. Thus, it is clear that regardless of having a good design of mechanisms, NESTORE will not be able to trigger any effect on users' health and behaviours if they do not feel engaged and get some sense of real support from the system.

In this regard, what should be avoided is user burnout and immunization to the interactions, which could be caused by either repetitive notifications or out-of-context interventions, for instance. In other words, what we aim to achieve is an emotional link between the users and the NESTORE platform, making them feel supported by the e-Coach whenever they need it, in an appropriate format and in a personalised manner.

For such purpose, the inclusion of knowledge processing algorithms and reasoning techniques is being implemented through the DSS so that, for instance, coaching plans could be personalized in terms of which kind of coaching activities are proposed, when they are sent –frequency, time of the day, etc.-, the total amount of recommendations to administer and their priority**.** This processing is based not only in the user profile –including either sensed, inferred or manually inputted (e.g., self-reported by the user) data- but also takes into account the context of each user. For example, the status of the user on the different target domains, the weather, and the temperature are items that will have an impact on the coaching plan proposal and its personalisation. All these techniques are encompassed inside the Decision Support System which is the core component that provides intelligence to all NESTORE modules and adequately integrates the interaction of a user's preferences, status and context.

In order to achieve this, the use of data mining techniques is encompassed for modelling user behaviour in a short-term timespan and then providing support to the user to select the most convenient coaching activities based on the implementation of a tagging system and other reasoning techniques. The DSS bases its online recommendations on a dynamic user profile model mainly constructed on the knowledge extracted from sensed as well as self-reported and performance data within the four NESTORE target domains.

The scope of this document is to report the actual design and development status of the DSS and evidencing the remaining future work that will be reported in the following deliverables of WP4 expected to be delivered in M24 together with the final implementation of the DSS.

The information contained in this document collects the inputs provided by WP4 partners in order to shape the best methods, tools and scientific background to provide the intelligence of the NESTORE system. The document is structured as follows. Section 1, introduces the background and position of the deliverable. Section 2 explains the methodological approach on which the DSS is grounded. Section 3 goes through the so-called "Coaching timeline": a three-layer system composed of pathways, coaching activity plans, and coaching events. Section 4 lists the main functionalities of the DSS. Section 5 describes the technical implementation of the DSS, including the architecture, data sources, data processing, the algorithms and implementation as well as the API services. Finally, section 6 outlines two data simulators implemented to help WP4 researchers to create the DSS models and test all the workflows involved in the system.

1.1 Relation with other work packages

The DSS is built upon the information coming from the sensing platform, the e-Coach apps and the context of each user. The information is gathered, processed and elaborated throughout different components of the NESTORE system to become useful information to be displayed to the user through the e-Coach developed in WP5. The process starts with the sensors where data from accelerometers and beacons are sent to the smartphone through specialised communication interfaces and processed by specific algorithms integrated inside it (WP3). These algorithms provide information about physical activity, sleep and social interaction. Similarly, for the nutritional domain the information comes from the LogMeal API, which interprets the photos of the dishes. Finally, the cognitive domain is assessed through serious games, computerized cognitive testing and a questionnaire capturing perceived memory problems. In T4.1 and T4.2, different post-processing algorithms transform the raw data into indicators (see D4.1.)

Thus, the DSS constitutes the software interface between the sensing platform developed under the umbrella of WP3 and the user-interface, and interacts with the motivational mechanisms designed and implemented in WP5. From a scientific point of view, the background knowledge comes from the different domain experts who researched, structured and reported in WP2 deliverables the general framework for healthy aging, providing a structured knowledge to characterize the users in terms of status and behaviour, as well as the evidence base for interventions targeting improvement in each domain in later life. Finally, the DSS is held under the umbrella of the databases and servers provided by the different tasks of WP6. Figure 1 presents the interconnections of WP4 T4.4. with the other WPs of the NESTORE project.

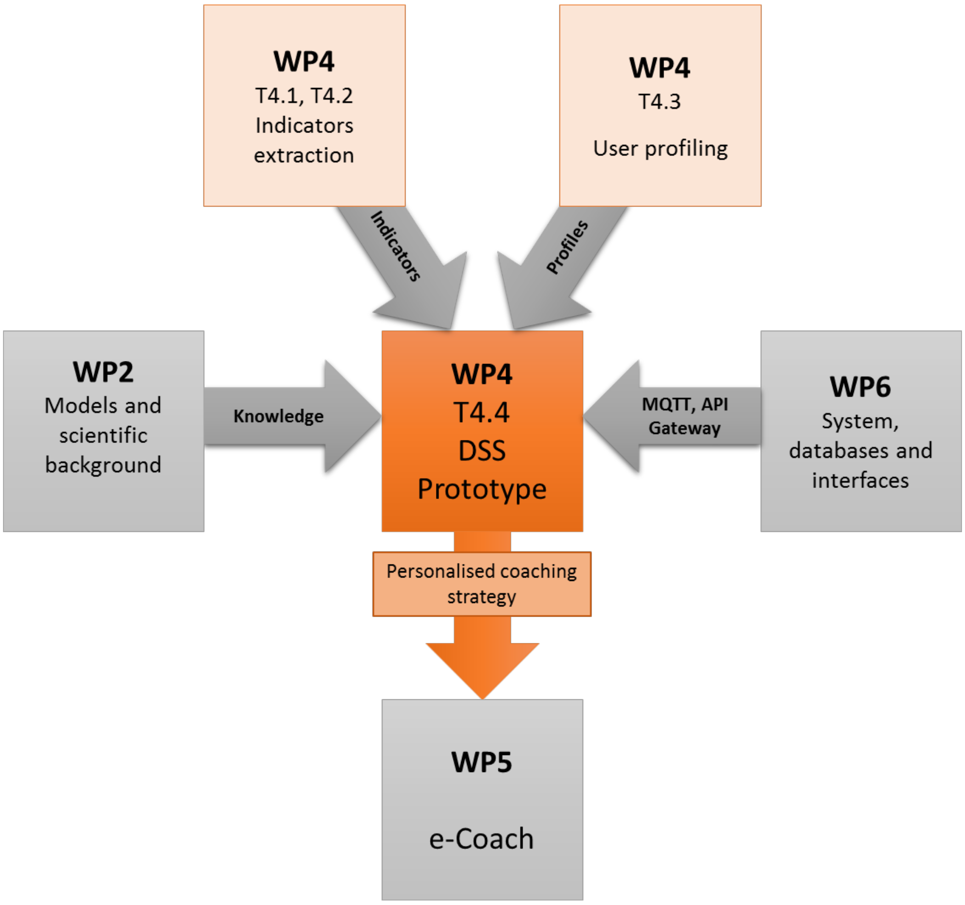

Figure 1. Graphical representation of the relationships among WP4 –T4.4, the activities of other NESTORE work packages, and the activities of other WP4 tasks

2 Methodological approach

NESTORE provides recommendations for coaching and personalisation in four crucial domains (called henceforth NESTORE target domains) of the Active Ageing process: i) physical activity, ii) social interaction, iii) cognitive functioning, and iv) nutrition.

NESTORE proposes a holistic approach in which the user is put in the centre. By putting all experts' knowledge together, NESTORE tries to understand the users with regard to the aforesaid target domains, assess their status in each of the areas, outline their habits and preferences, and guide them through the health behaviour changes they want to carry out. With this aim, users will choose what they want to change and how they want to put that into action. In other words, users select the pathway they want to execute with the support of the e-Coach, which keeps learning from users' behaviour so as to suit their individual needs.

It is grounded on the Health Action Process Approach (HAPA), a model for describing, explaining, and supporting behaviour change in health-related domains (see D2.1. and D5.1.). With respect to other behaviour change models adopted so far for coaching in the area of health behaviours (e.g., Theory of Planned Behaviour (TPB)), the HAPA model identifies specific variables that best support the user during the actual phase of behaviour change that follows intention formation (whereas TPB identifies only variables affecting the intention-making). It is implemented in NESTORE by matching specific behaviour change techniques (BCTs) to the aforementioned variables and implementing them in the interface (see D5.1.).

The DSS can be considered the intelligence of NESTORE. It processes data in order to help users take decisions in complex situations due to a large number of indicators expected to be measured (see D4.1.). Its aim is to develop the data analysis elements needed to provide NESTORE e-Coach with tailored feedback based on integrated data sources encompassing the four target domains, helping users to select the most adequate activities towards healthy habits.

The DSS is based on a Knowledge-based System. This system holds a collection of general principles which can potentially be applied to various problems. These principles will be stored in the knowledge base.
The knowledge base (KB) is stored in the NESTORE cloud and is modelled using the elements and relationships defined in WP2 deliverables. This KB is the source and destination of data consumed and produced by WP4 reasoning processes. It contains both the necessary inputs (target domain parameters, demographic data, etc.) and the established pathway for each profile, and also the outputs generated in WP4 which are profiles in the different domains as well as the recommendations in form of the designed pathway to foster healthier habits.

3 The coaching timeline

During the first two weeks after users sign up to NESTORE, the system gathers information about them through the chatbot to build their user profile. These data are used as input into a three-layer process proposed to adapt better to users' needs and preferences (in addition to information gathered during a baseline assessment during the pilots that takes place prior to the two-week daily life assessment period and the installation of and training on the NESTORE system in the users' homes).

In Annex 1, we explain in depth the layers that form the aforesaid system.

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4 The DSS functionalities

The following are functionalities utilised by the other NESTORE system modules in order to: (i) extract and summarize the necessary indicators that involve the holistic model of the user; (ii) provide a more targeted approach to behaviour change, aim to foster change in poorly performing domains present in the user; (iii) help users in deciding when and how to perform the coaching plans.

Set I: Extraction of indicators

i. Data analysis, data cleaning, mapping, manual and semi-automatic categorisation, data comparison (e.g. data correlation) and trend detection on the four target domains;
ii. Provide a dynamic multi-scale modelling of user-specific data based on semantic annotations.

Set II: Building personalised coaching plans

iii. Combine and interpret the different signals coming from extensive sources of information, to provide meaningful, timely, and relevant tools to help users select the best pathway for them, CAPs and CEs according to their health status and preferences;
iv. Help users to adapt coaching activities to their needs and preferences, e.g., lowering the intensity of physical activity if the perceived required effort is too high;
v. Provide social support, checking and suggesting available friends or family members that can join the users perform the planned and suggested activities.

Set III. Action Planning

vi. Help users schedule the proposed coaching activities into their calendar, matching user availability with context requirements (e.g., weather conditions);
vii. Support the e-Coach in scheduling and personalising the educational messages for increasing risk-awareness or informing about outcome expectancy.

The functionalities already implemented in the first prototype of the DSS are reported in chapters 5 and 6 of the present document. The ones related to profiling will be further explained in D4.3. and the ones implemented in the final prototype will be reported in D4.4.

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4.1 Use-cases and outputs

Two use-cases that symbolise real possible scenarios are described in this chapter. These types of scenarios are used in WP4 to analyse the needs of data analysis and preparation that NESTORE might need from the tasks involved in the development of the DSS.

4.1.1 Use case 1: A fit woman aged 65 who could improve her memory

Maria is a 65 year-old retired person, who lives in Barcelona with her husband. She enjoys swimming in the beach during the summer and some Sundays she goes out hiking with her family. With the exception of those activities, she leads a sedentary life. She wants to stay fit and healthy, so she tries to keep a balanced diet. Nevertheless, her grandchildren have been saying to her for some months that she tells the same story multiple times without her being aware.

One day, she hears of NESTORE in the handicraft workshop that she usually attends. Her friends are talking about it and they decide to start using it for having fun while controlling their health status. She is also very interested in knowing more about nutrition, so she takes photos of her dishes almost every time that she eats.
Maria has been using NESTORE for the last two weeks and the system has noticed that she could improve her memory and that she rarely walks 10,000 steps a day. A new message appears on her e-Coach interface...

The system proposes her a pathway to wellbeing that involves activities from four different health domains: physical activity, nutrition, social interaction and cognitive functioning domains. She sees that the proposed activities are personalised (e.g. she receives many recommendations involving walking since she indicated her preference on this activity), so, although she could choose an alternative pathway, she decides to go for the one recommended by the system. Since "Improve memory" is one of the objectives to tackle, she receives some specific questions about her preferences on this domain.

After some days using NESTORE, she realizes that the system is focused on helping her to achieve her goal. For example, the e-Coach helps her to plan her activities during the week, and even proposes to have a walk in beautiful places when she is nearby one of them! A couple of days later, she gets a new reward in the game: now she can decorate the cockpit of the boat because she has succeeded in navigating the labyrinth of the game and collecting the relevant stimuli three times in a row for the first time!

Although the e-Coach is focused on the pathway that Maria has selected, the e-Coach shows information about her behaviour in all domains, so she has discovered that her calcium intake is below the recommended threshold, according to NESTORE.

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4.1.2 Use case 2: A man with an unhealthy diet

Peter is a 70-year-old man who has recently became widowed. He only cooks basic dishes and not very diverse because it was his wife who used to cook at home. He has good mental skills and plays cards with his friends every Tuesday and Thursday, when they meet to have breakfast while playing and chatting. With the aim of going out much more and being more physically active, Peter joined a group of nordic-walking some months ago with his friends, and he really enjoys it! In fact, he's starting to feel fitter since he practices this sport.

All in all, he feels healthy and fit. However, this morning he went to the general practitioner to get the results of the blood tests he took last week and the GP detected that Peter has a little bit of iron deficiency anaemia, so he's advised to eat more red meat. He explains the GP that lately he's not having a very healthy diet because he wasn't really aware of the problems that it could unleash.

The day after, while playing cards with his friends, he explains the discussion that he had with the GP and that he doesn't know how to handle the problem. One of his friends, Mark, explains that there's a new application called NESTORE that could help him get recommendations about healthier habits. Mark says that it's not only good for his nutrition condition, but also for keeping a healthy status with regard to his memory skills and his physical activity. In fact, it was using NESTORE that Mark knew about the nordic-walking group. Mark shows the NESTORE application to his friends and a couple of them get excited about it. Peter decides to give it a try since he needs a coach that guides him through this necessary behaviour change phase.

Peter signs up to NESTORE and he is asked about and tested on his status in different areas, ranging from his social situation to his physical condition. The e-Coach detects that Peter could keep doing what he does to maintain his physical and cognitive status. However, it identifies his diet could be healthier and that he feels lonely after his recent loss.

Some months after the e-Coach encouraged him to improve his social integration, he has changed his weekly routine. Now, he does not do groceries once per week anymore. He goes twice per week to the bakery around 11am so he can chat a bit with the baker, who is a funny young man that always has a joke to tell. He goes to the market every Saturday so he gets seasonal fruits and vegetables, as the e-Coach recommended to him. When the e-Coach suggests a new recipe to do, he goes to the supermarket that is five-minute walk from his home to buy the necessary ingredients. Now, all these shop assistants know him and he feels his social network has increased. Now, Peter has increased his culinary knowledge and he has integrated his community in the process.

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5 The DSS technical implementation

The NESTORE system is built upon mHealth and cloud computing technologies, which are articulated to analyse users' behaviours in the four target domains. In Figure 2, we show a high-level functional architecture divided into four big blocks which are a) data sources, which encompass all the inputs to the system; b) data processing, divided into short-term and long-term indicators extraction; c) the decision support system, where the intelligence of NESTORE is built, and d) the output of the system, which are personalised coaching plans.

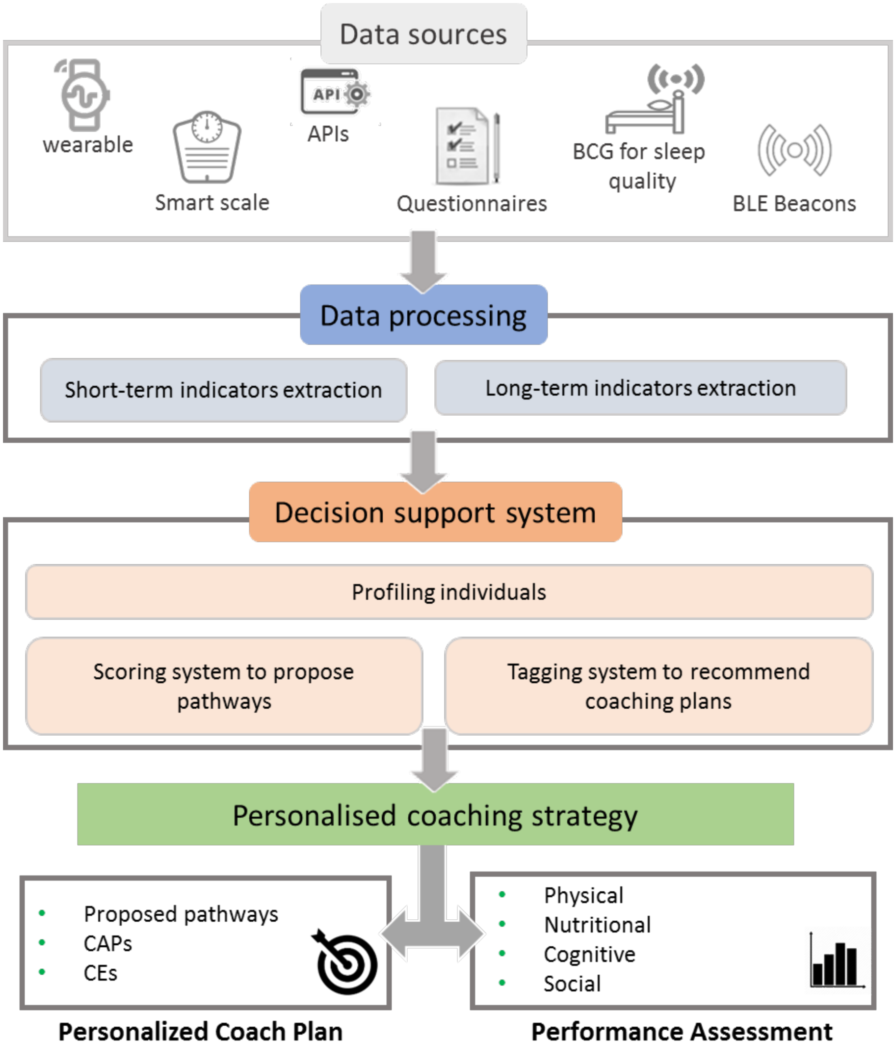

Figure 2. General Architecture of the DSS in NESTORE

All these blocks are built in a modular manner, so that the whole system can be improved according to new requirements and processes designed throughout the other NESTORE modules. The core of the DSS runs in NESTORE cloud in a Virtual Private Server (VPS) (see D6.3).

As can be observed in Figure 3, the design follows a Software as a Service solution (SaaS), with a module called *Interfaces* which is the source and destination of the inputs and outputs of the DSS. Its main modules are implemented in Python and respond to the functionalities pointed out in Figure 3:

- the long-term and short-term analysers perform the reasoning processes. Some outputs directly feeds the DSS with new indicators, other outputs go to the e-Coach (i.e. visualization) as feedback of the activity performed (e.g. face2face meetings for social, sleep monitoring, weight) as reinforcement for the user.

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- the database connector contains the utilities to store and retrieve the necessary data to run the reasoning environment;
- a configuration file holds the required tokens and other configuration elements needed to perform calls to other modules;
- the external APIs connector is the link to other NESTORE services (i.e. Logmeal), and to context APIs (i.e. weather), which are inputs to the DSS.

Two simulators of synthetic data (user profile and sensor data) are also designed and implemented under the umbrella of WP4. The generated data are inputted into the DSS general database in a testing environment accessible to all NESTORE partners. The current status of these implementations are reported in chapter 6 of this document.

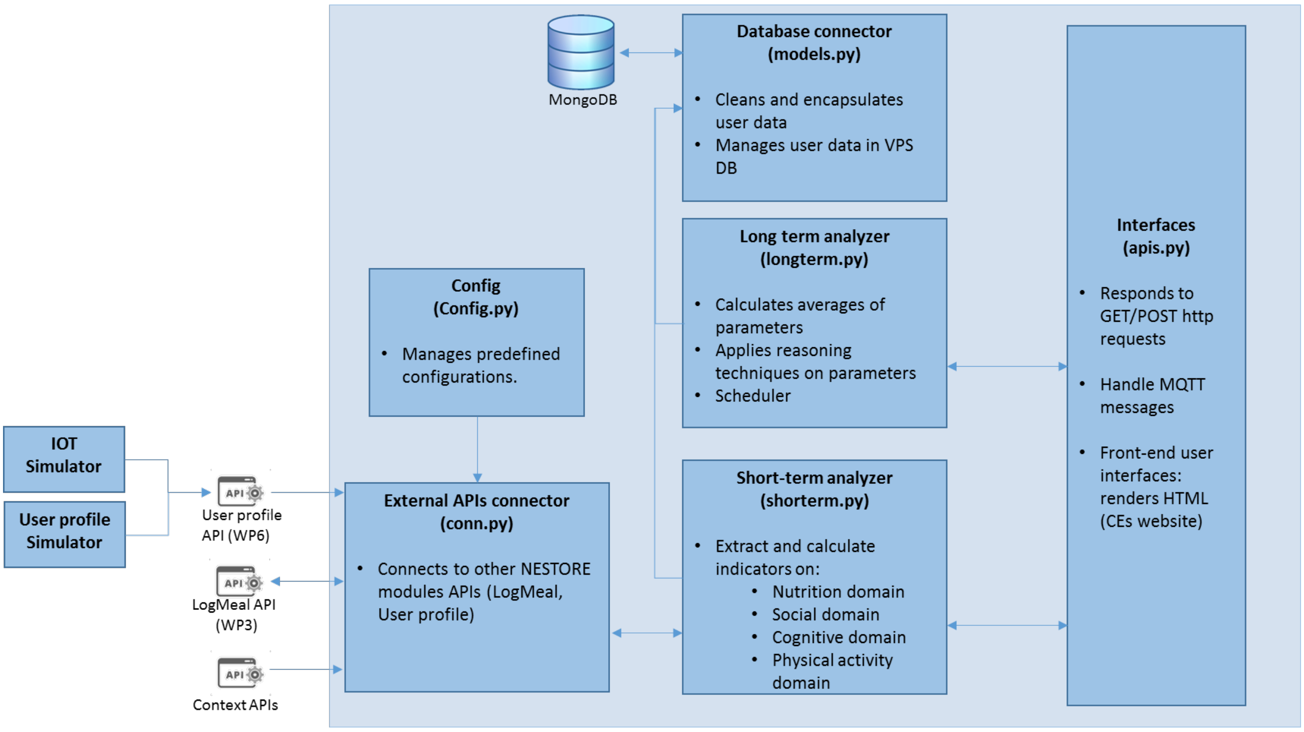

Figure 3. Internal components inside the DSS

The reasoning system also holds a collection of specific details that apply to eventual problems for specific users in a certain timeframe. These details are stored in the working memory which is implemented in a Mongo database.

5.1 Data sources

NESTORE data sources are divided in two main categories: *hard* and *soft* data sources. The former corresponds to the stream coming from environmental (i.e., any sensor deployed in the users' vital space) and wearable (i.e., the device worn by users during their daily activities) devices and tests presented through the e-Coach, hereinafter referred to as *Sensing system*. The latter consists of derived data coming as a result of computation or fusing strategy (i.e., *Food recognition*), data coming from web and third parties' APIs (i.e., *Context*), and data coming from a direct input of the user (i.e., *Questionnaires administered through the e-Coach*).

5.1.1 Sensing system

It is composed of a wearable device, able to monitor the physiological parameters of the user, and an ensemble of environmental wireless devices that detect the status of the user's living space, such as house air quality, and

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her behavioural data, such as movements in the house, sleep quality, interactions with point-of-interests in the house and other people.

For each target domain, a subset of variables are monitored in order to address the requirement of unobtrusiveness coming from the requirement elicitation phase. As a result of the sensor selection under these requirements, the following devices are installed:

- A wearable device to monitor physical activity types and levels, heart rate, and cardio-respiratory exercise capacity during free-living non-structured activities (i.e., any kind of physical activity performed during the day) and structured activities (i.e., planned, structured, repetitive, and/or purposeful physical activities);
- A smart scale for body composition analysis, which encompasses percentage of fat mass, muscle mass, water, and bone mass;
- A ballistocardiograph (BCG) device for sleep quality analysis, in terms of perceived calm sleep; sleep efficiency; total sleep time; sleep onset and offset; time in bed; sleep onset latency; wake after sleep onset; number of awakenings;
- Fixed BLE beacons installed in meaningful points-of-interest in users' homes (e.g., fridge, TV, wardrobe, door) able to detect the proximity of the user, the relative humidity, and the temperature of the point.
- Mobile BLE beacons to be provided to secondary users (i.e., caregivers, relatives and friends of the user) in form of keyfobs in order to detect social interactions, monitoring their duration, function, location and frequency.

From the architectural point of view, in order to reduce the effort needed by the end user to install and use the environmental sensors, a Web of Things (WoT) [1] approach is adopted. Such smart devices will then be able to communicate with each other using existing Web standards. In particular, BLE beacons' advertisements are collected by the wearable device and then sent to NESTORE cloud by means of a WoT agent running on the user's smartphone via Wi-Fi, when indoor, or via mobile connection, when outdoor. The smart scale and the BCG device will send data to the cloud back-end via Wi-Fi.

5.1.2 Food recognition

The LogMeal API [2] (see D3.1) is used to automatically construct a food diary, based on images acquired by the user with a smartphone to objectively and seamlessly collect food intake information.

5.1.3 Questionnaires administered through a chatbot

The inclusion of a well-assessed psychological empowering modelling in the system intelligence guarantees an improved adherence of the users to the CAP with respect to more conventional coaching approaches.

5.1.4 Context

User engagement is improved by not only personalising the proposed CAPs based on the user's status and preferences but also by adapting them to each user's context. To achieve this, a series of context data types have been identified to be used at different stages in the personalisation process. The context data controlled in the DSS are:

- Day information: Weekend, weekday, free day, etc.
- Weather information: Retrieve if in the current moment it is sunny or it is raining, temperature, etc. In the majority of cases it is only used to know to know if the day is good to do some exercise on the outside.
- User location: Retrieve the actual position of the user. With this information, we can know if it is near some relevant places.

The different identified context data sets can be grouped into two main categories of context data types:

- Simple context data types: the ones that identify an absolute or basic measure of user context, such as the current time or its raw GPS location.
- Complex context data types: the ones that interpret some abstract information of a user context, often elaborated from other data sources or simple context data types, such as the weather conditions in the users' location.

In more detail, the identified sets of context data are the following:

a) Time data
Time data are user basic context data that indicate the current time in the user location. These data help identifying at what time of the day a specific event happens, which may affect on how these data are processed and reacted upon.

b) Location data
Location data are user basic context data that are directly and easily gathered from the smartphone and indicate the current location coordinates of the user, taking the most precise location from the available sensors. These data help identifying where an event happens, which may affect on how these data are processed and reacted upon.

c) Weather data
Weather data are user complex context data that indicate how the weather feels like in this moment in a specific location. These data are processed from raw data sources providing weather information (such as openweathermap.org) to be further processed in order to provide a high level overview of current weather –rainy, snowy, too hot, too cold or sunny. These context data are common for many users at a time (more specifically, for all the users of a given location) and, therefore, will be delivered by a dedicated cloud API that will be easily consulted by any NESTORE app or service.

5.1.5 Serious games

In the first prototype of the DSS, the integration with serious games is not yet performed, so it will be reported in D4.4.

5.2 Data processing

Among other features, the DSS takes advantage of both mHealth (smartphone apps and wearables) and cloud solutions to perform a two-stage processing of the user-generated data at different timespans to provide different levels of feedback as depicted in Figure 6.
On one side, the DSS collects user data from the connected wearables, sensors from the IOT platform external APIs and manually inputted data. Collected data, which encompass indicators of the pathways, are cleaned and then fused into daily aggregated summaries (24h timespan) that are finally stored in a repository in the cloud for further processing. Additionally, collected data in those 24h timespan are continuously analysed to provide responses to detected events.

On the other side, the NESTORE cloud consumes those daily aggregated summaries stored in the repository to build a longer timespan summary to be further analysed. This long-term analysis is in charge of user preferences and trends, and evaluate the user's progression. As a result, it provides behavioural personalised coaching plans and recommendations based on performance assessment on the four target domains.

5.2.1 Short-term indicators extraction

The NESTORE ecosystem is based on a collection of applications and sensors that generate real-time continuous streams of data. These data are characterised by being extensive or even limitless. One of the latent challenges of this project is to extract knowledge from these streams of data in order to both facilitate subsequent decision making and infer valuable information. Mining these streams following the holistic model proposed in NESTORE brings new ways of deriving potentially useful information permitting broader assessments.

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One of the assessments implemented as part of the DSS is the short-term reasoning, where sequences of data are processed and transformed into classifications of users' daily behaviour. Those classifications are later analysed, to be used as a motivational element in the e-Coach (refer to WP5 deliverables).

Short-term reasoning is performed with the intention of giving information to the user about her performance or simply to update the system with new knowledge. The procedure to do so goes through the following stages (see Figure 4): i) *data gathering*, where sensor data and data from the different applications are collected; ii) *data preparation*, where data gathered are arranged, formatted, cleaned and transformed; iii) *extraction of indicators*, which are basic variables that provide input to the reasoning model; iv) *reasoning and short-term events detection*, where knowledge-based reasoning techniques are applied for identifying, classifying the data and fire conditioned events; v) *notification,* where the e-Coach is informed. The first 3 stages are implemented in T4.1. and T4.2. and reported in D4.1, while the other two are implemented in T4.3 and T4.4. and will be reported in D4.4.

Figure 4. Procedure for short-term data extraction

5.2.2 Long-term indicators extraction

Long-term behaviour is the sum of short-term behaviour assessments of the system that captures the general trend over a longer period. This allows the system to assess if behaviour change has indeed occurred in the user, and is not just a temporary fluctuation of their habit.
The following concepts are used in modelling the conduct of a user associated with long-term outcomes (see Figure 5):

- *Observable indicators*: A subset of the parameters that have sufficient data (daily entries) to be analysed by the system in the long-term period. Determined by:
    - Equipment (what sensors does the user have) e.g. if the user is not using the sensor that monitors sleep, the indicators related to sleep wellness is not observable.
    - Engagement (how often does the user enter data into the system or use the sensor equipment) e.g. if the user does not enter meal photos frequently, the indicators related to nutrition are not observable.
- *Monitored indicators:* A subset of current observable indicators that the user has at some point selected to improve in as a long-term coaching plan.

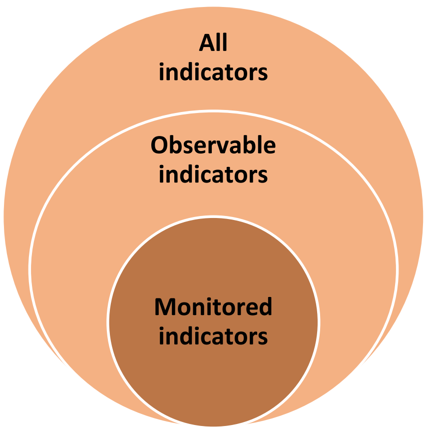

Figure 5. Subset of indicators used to perform long-term assessments

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The foreseen methodology of this module is expected to be contained in the following two blocks:

1. A first block aimed to clean the gathered data and generate datasets.
    a. Ensure data collection correctness and integrity
    b. Discard data and/or indicators that do not provide enough information or will introduce errors
    c. Identify outliers and "out-of-range data" and discard them if it is pertinent
    d. Handle missing data
    e. Create and assemble the datasets
2. A second block to describe the important findings identified exploring the data:
    a. Analyse the main characteristics/indicators in the long-term
    b. Trend behaviour, correlations and cluster analysis to find generalisations (i.e., structure of a "normal day").

The implementation of this methodology and the methods used to extract and measure the long-term indicators will be explained in D4.4. together with the final prototype of the DSS.

5.3 The DSS algorithms and implementation

The DSS bases its personalization process in the creation of a 'User Model' based on the integration of multi-parametric data in order to develop personalised strategies to support the decision support. Concretely, the models are fed with the necessary data explained in D4.1. and other data used for the personalization process. This method is called "Profiling individuals" and conforms the main element for personalisation of the DSS. A scoring system and a tagging system are also part of the methods implemented in the first prototype of the DSS, they are the core elements of the recommendation system.

5.3.1 Profiling individuals

NESTORE aims at knowing the user "intimately" so it needs to know and understand habits, the environment, the social life and other key information about the user, including the health status. To this purpose, a two-fold user profile is proposed and used by the DSS to build the 'User Model':

- *Static profile:* It is formed by the status and preferences of the user and it is characterised by containing non-varying attributes. Concretely it includes demographic characteristics, attributes regarding the context where the user lives, preferences and baseline data of the various domains.
- *Dynamic profile:* It is built dynamically while receiving data from sensors, applications and contextual APIs. It is foreseen to receive daily indicators about the different domains and also contextual information.

For such a system to work effectively, a person's goals and overall status in the target domains needs to be assessed together with a profile of a person's daily life activities monitored using technology-based tracking systems in order to provide a reference frame and basis for the DSS that includes an individualised real-life approach rather than a mere population-based approach founded on maximum performance laboratory-based assessments [3].

Thanks to the aforesaid data sources and to the system intelligence able to learn and adapt to users' specific behaviours and context, NESTORE creates a detailed, reliable, and dynamic user profiling, which is the base to build personalised guidance and advice, and to monitor the coach effectiveness in preserving overall wellness in the older population. Figure 6 depicts the different categories taken into consideration in the profiling of users.

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Figure 6. User profile summarised per category

5.3.2 Scoring system to propose ranked pathways

Based on the pathways of interest, NESTORE experts conducted a search of normal values and cut-offs relative to each pathway. Further information about this system is documented in Annex 2.

5.3.3 Tagging system to recommend coaching plans

Once the user chooses the pathways and CAPs to focus on, another subsystem of the DSS, the tagging system, comes into play by proposing appropriate CEs to users. Annex 3 explains the specifications of this system.

5.3.4 Deciding when to prompt questionnaires

During the first two weeks, the e-Coach asks questions to the users in order to gather all the data the DSS needs to assess the baseline of each pathway and build the user profile to personalize the recommendations. Moreover, the e-Coach also explains how will NESTORE interact with them and how can they interact with NESTORE. Among others, the e-Coach will explain the meaning of the charts that will be displayed through the app, and how can users track food consumption through the chatbot.

All that information is asked to users in independent messages. In order not to barrage them with questions, the DSS will try to prompt the e-Coach to ask questions in the manner that bothers them the least. One idea is based on modelling users' days. The DSS will take into account when users wake up, have lunch, exit and enter home, and go to bed, among others, in order to build a model that forecasts when users will be more receptive to have a conversation with NESTORE. Thus, only when the DSS knows that users are at home and probably not planning to go out, a signal will be sent to the e-Coach so as it makes contact with them.

A detailed explanation of the timing of each question will be presented in future deliverables of WP5.

5.4 DSS API Services

The different modules inside the DSS provide specific data regarding pathways and CAPs that the user is following, and static and dynamic attributes of the user profiles in the four target domains. A set of methods are published for each of the areas. Here we list some examples:

Set I: Pathway selection

- <u>Proposed pathway [GET]:</u> Get the proposed pathway for a given user
  - *Output*: the recommended list of pathway ranked depending on users' specific needs
- <u>Selected pathway [PUSH]:</u> Confirm the pathway that the user will focus on
  - *Output*: OK/NOK in case there is any format error

Set II: Static and dynamic attributes of a users' profile

Specific to nutrition domain:

- Upload photo [POST]: Upload a photo to get food recognition
    - *Output*: the recognized type of food (dish, ingredient or drink) and a list of recognized food containing the most probable one and other alternative dishes.

- Modify type [POST]: Modify the type of food
    - *Output*: a list of recognized food given the indicated type.

- Confirm dish [POST]: Confirm the dish/ingredient/drink recognized by the system as the one ingested by the user.
    - *Output1*: An educational message to be shown to the user. It depends on the food group of the dish.
    - *Output2*: The calculation of nutrients of the selected dish.

- Add refused foods [POST]: Aggregate more types of food to the list of food preferences of a user
    - *Output*: OK/NOK in case there is any format error

- Get refused foods [GET]: Get the list of current food preferences of a user
    - *Output*: […]: The current list of refused foods

- Get all classes [GET]: Get all the available ingredients, drinks and dishes that the system is able to recognize
    - *Output*: A list from LogMeal API with the classes in JSON format and contextualized depending on the language of the user.

- Get summary of a dish [GET]: Get summary of the nutrients of a dish
    - *Output*: type of meal, nutrients and timestamp of a given dish

- History of dishes per month, week or day [GET]
    - *Output*: List of dishes uploaded during the specified period

- Get summary of a period[GET]: Summary of the nutritional information
    - *Output*: Summary of nutrients given a period

- Get thresholds [GET]: Get the personalised thresholds for every nutrient given the cut-offs provided by nutritionists.
    - *Output*: Thresholds per nutrient for a given user

Specific to cognitive domain:

- Push questionnaire responses [POST]: Send the responses of a questionnaire
    - *Output*: the responses of a questionnaire in the format: {"idquestionnaire":id_q,"userid": uid, "timestamp": dd/mm/yyyy, "replies": {[uid1, rep1],[uid2,rep2]...[uidn, repn]} }

6 Simulators and monitoring interfaces

6.1 IoT Simulator

Virtual living lab is a software component designed to simulate sensor data in early phases of the project for testing purposes. This tool is capable to produce single or repetitive measures over time, depending on statistical models, configured via parameters. It simulates the measures like in a real scenario with a default ordinary behaviour, with a probability of changing it to a certain degree, or produce data replicating preconfigured irregular behaviour. This allows the virtual living lab to simulate and test the standard operational mode of the project, and also be able to reproduce abnormalities that should be detected by the project implemented algorithms or sets of rules.
Two different operating modes are available, offline or online. The offline mode generates historical data to populate periods of time with information, whereas the online mode produces real-time data, simulating a real environment. This allows to create historical data to be shown in interfaces and have also prior data for algorithms for example, as well as simulate the introduction of new data at every moment for the real-time consumption of the projects infrastructure.

Goals and features of the virtual living lab:

- Simulate and produce sensor data
- Test the standard operational mode of the project
- Reproduce abnormalities that should be detected by algorithms or rules
- Data dependent components can be tested and used from the start of the project
- Detect flaws on the architecture, design or protocol before building the real infrastructure
- Stress tested from the beginning in all different environments
- Simulated data to show in the interfaces for divulgate purposes

6.1.1 Requirements

The Virtual Living Lab is implemented in Java, using mainly the Quartz library to schedule Jobs, and then depending on the transition protocol, libraries for the communication with rest of the platforms Software. Therefore, the hosting server would need:

1. Java7 or Java8 for executing the jar file
2. Resources depending on the stress testing to perform (2 cores + 2GB RAM should be enough for most scenarios)
3. Communication to the rest of the projects software

6.1.2 Configuration

The Virtual Living Lab is a jar that is launched with parameters:

java -jar nestore-simulator.jar [config_file] [OPTION]

- **[config_file] -> Configuration file containing configurable parameters**
- **[OPTION] -> Special launch parameters:**
  - **-g, --generate: needs 2 arguments more, start/end date (dd/MM/yyyy). Generates data between these days. Both included**
  - **–h, --help: Explains possible usages**

The configuration file is a java properties file with the following fields:

```
httpHost=https://datastore.robofuse.com
urlPostBeaconMeasures=/api/beacon_sensor
```

```
# 0 to not send periodic motion during day, 1 to send
periodicMotion=1
# seconds between periodic motions during day
minIntervalData=5
# irregularity=0 -> not irregular. irregularity>0 -> 1/irregularity chance a day is irregular
irregularity=0
```

The configuration file specifies the URL of the NESTORE server so it can be executed for different environments and also parameters related to the data production. In the previous example there is periodic data sending (every 5 seconds) and there are no irregular days (days which the user behaves anomalously).
Finally, there is also a home configuration file, that specifies the layout of the house in json format. Here a reduced example:


```
{
	"userid": "example",
	"sensors": [
		{
			"id": "BEACON1",
			"mcodes": ["BEACON", "BAT", "TEMP"],
			"info": {
				"UUID": "B0011"
			}
		}, {
			"id": "BEACON2",
			"mcodes": ["BEACON", "BAT", "TEMP"],
			"info": {
				"UUID": "B0010"
			}
		}
	],
	"spaces": [
		{
			"id": "kitchen1",
			"type": "kitchen",
			"description": null
		}, {
			"id": "living1",
			"type": "living",
			"description": null
		}
	],
	"setup": [
		{
			"sensor_id": "BEACON1",
			"room_label": "kitchen1"
		}, {
			"sensor_id": "BEACON2",
			"room_label": "bedroom1"
		}
	],
	"topology": [
		["living1", " kitchen1"]
```


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```
        ]
}
```

This file contains:

- **Sensors**: The sensors installed
- **Spaces**: Rooms of the house
- **Setup**: The room in which the sensors are installed
- **Topology**: The connection between the rooms

6.1.3 Data outputs for NESTORE simulated platform

The different version of the Virtual Living Lab produces different data outputs; therefore, we separate them into versions.

V1.0 (23/11/2018)

1. Sending information to 1 user (fixed beacons UUIDs)
2. No irregular days (configurable)
3. Beacons measures:
    a. Every 5s (configurable)
    b. RSSI: -50 to -40 (in room), -110 to -90 (not in room)
    c. Temperature: from 22ºC to 26ºC
    d. Humidity: from 50% to 70%
    e. Battery: 100%
    f. Motion: false
4. Room visited distribution on regular day:
    a. Go to sleep (user is in bedroom): 23-23:59
    b. Wakeup (user leaves bedroom): 07-07:59
    c. Visits bathroom during night (short period in bathroom): 1 to 3 from 4-10 minutes
    d. Shower (in bathroom): 20-35 min after wake up and takes 10-20 min
    e. Prepare dinner (in kitchen): start 20-20:59 and duration 20-40 min
    f. Dinner (in living room): start 0-2 min after prepare and takes 30-40 min
    g. Home leavings (no reading): from 13 to 19h. 0-2 leavings per day
    h. Visits: from 9 to 13h. 0 or 1 visits per day (prepared, not executed)

6.2 User profile Simulator

The simplest approach to get users' data would be to create users assigning a value randomly drawn for each of the variables. However, that could lead to very unreal scenarios; consequently, that line of action is ruled out.

To assure the reliability of the created users, the methodology used to develop the static profile simulator is twofold: restrictions are applied to avoid nonsensical scenarios, and statistical indicators are used to mirror the population of older European citizens.

The target population of NESTORE can be characterized by statistical indicators such as the ones provided by *Eurostat*. Eurostat is the statistical office of the European Union; whose mission is to provide high quality statistics for Europe. Eurostat offers a compilation of indicators ranging from general and regional measures, to economy and finance indexes, to population and social conditions indicators.

Demographic indicators are drawn to simulate the population by age and gender per country [6]. A summary of this information is presented in Table 1.

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Table 1. Demographic indicators per country. It depicts the distribution of older people (age of 65 to 75) per country in Europe. Source: [6].

Country	Older population of Europe (%)
Bulgaria	1.63
Czech Republic	2.26
Hungary	1.91
Poland	6.37
Romania	3.47
Slovakia	0.89
Denmark	1.26
Estonia	0.24
Finland	1.23
Iceland	0.05
Ireland	0.71
Latvia	0.39
Lithuania	0.53
Norway	0.94
Sweden	2.09
United Kingdom	12.44
Croatia	0.81
Greece	2.07
Italy	12.71
Malta	0.09
Portugal	2.15
Slovenia	0.38
Spain	8.39
Austria	1.69
Belgium	1.99
France	11.95
Germany	16.32
Luxembourg	0.08
Netherlands	3.38
Switzerland	1.56

The static simulator will be further explained in D4.3.

6.3 Website to add and edit CEs

An administrative interface has been developed for testing and visualising graphically the Coaching events and their associated tags. It is used to facilitate the work between researchers of WP4, who are the ones implementing the tagging system reported in section 5.3.3, and domain experts, who did the research and design of the best coaching events for every of the NESTORE target domains.

The tagging panel can be accessed using the URL: https://api.nestore-coach.eu/dev/eurecat/dss/personalization. (see a screenshot in Figure 7). It contains a table with the following columns:

- *Domain and Pathway:* the target domain and pathway to which the coaching event belongs to;
- *Coaching activity plan:* the type of activity of the coaching event;
- *Coaching event:* the specific name of the event or activity;

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- *Tags:* the associated tags that characterize the event. There are three main types:
    - *Related to context tags*, like weather or place;
    - *Related to user profile tags*. Including both, constrains on the dynamic profile (e.g. current steps are low), and on the static profile (e.g. lactose-intolerant);
    - *DSS internal tags*, which are used by the system to perform the selection (i.e. the coaching activity plan is transformed into a tag in the case of nutrition, so that the DSS is able to recommend in a more diverse way).
- *Submit:* contains *Edit* and *Remove* buttons. The edition and deletion actions are replicated in the corresponding database, so that the tagging system and the related models are re-calculated when any change is done through this platform.

Apart from editing and submitting the tags from the website, the tags and coaching events can be automatically uploaded through a specific API.

- <u>Add CE [POST]:</u> Add a new CE with all the related parameters (domain, pathway, CAP and tags).
    - *Output*: OK/NOK

- <u>Add CAP [POST]:</u> Add coaching activity plans. This is used to fill the select fields on the webpage with all the possibilities of CAPs designed by the domain experts.
    - *Output*: OK/NOK

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DSS Personalization

Type something in the input field to search the list for specific items:

Search..

Domain	Pathway	Coaching activity plan	Coaching Event	Tags (weather, places&facilities, pet, stairs, garden, accompanied/alone, intolerances, Internet)	Submit	
Nutritional	Healthy eating habits	Eat more meat	Eat meatloaf for lunch	meat	Edit	Remove
Physical	Body balance	Going downstairs (more than 2 floors) (lower limbs)	When going shopping, take the stairs	stairs	Edit	Remove
Nutritional	Healthy eating habits	Eat more fruit	An apple a day keeps the doctor away. Eat some fruits	apple fruit	Edit	Remove
Physical	Fitness level	Dancing	Put a song and dance or join a dance course	dance	Edit	Remove
Nutritional	Healthy eating habits	Drink more water	Keep a bottle of water always next to you and try to finish it	water	Edit	Remove
Cognitive	Everyday mental skills	Take up a dance class	Join a swing course	dance accompanied	Edit	Remove
Social	Social integration	Join a theatre group	Join the "Poblenou" theatre group	accompanied Barcelona	Edit	Remove
Physical	Fitness level	Walking with the dog	Go out with your dog	dog	Edit	Remove
Physical	Fitness level	Slow walking	Why you don't go to buy something to the mall by feet?	shopping mall city center	Edit	Remove
Physical	Fitness level	Brisk walking or nordic walking	Why don't you go out and enjoy the nature?	park mountain hill poles	Edit	Remove

Figure 7. Screenshot of the administrative interface to add CEs

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7 References

[1] T. J. a. P. H. R. Maurer, “A comparison of Likert scale and traditional measures of self-efficacy,” *Journal of applied psychology,* vol. 83, no. 2, p. 324, 1998.

[2] D. a. T. V. Guinard, “Workshop on Mashups, Enterprise Mashups and Lightweight Composition on that Web (MEM 2009), in proceedings of WWW (International World Wide Web Conferences),” in *Towards the web of things: Web mashups for embedded devices*, vol. 15, Madrid, 2009.

[3] E. a. B. M. a. R. P. Aguilar, “Food recognition using fusion of classifiers based on CNNs,” in *International Conference on Image Analysis and Processing*, Springer, 2017, pp. 213-224.

[4] M. a. W. R. a. R. C. a. B. S. M. Martin, “Semantic Activity Analytics for Healthy Aging: Challenges and Opportunities,” *IEEE Pervasive Computing,* vol. 17, no. 3, pp. 73-77, 2018.

[5] P. a. H. C. a. M. J. a. S. M. A. Bonhard, “Accounting for taste: using profile similarity to improve recommender systems,” in *Proceedings of the SIGCHI conference on Human Factors in computing systems*, 2006, pp. 1057-1066.

[6] The-NESTORE-Consortium, “D2.3: The NESTORE specific ontology,” https://nestore-coach.eu/deliverables, 2018.

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