Dynamic Decision Support System for personalised coaching to support active ageing

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Abstract. Physiological status and physical activity, social interaction, cognitive and emotional status, and nutrition in older people are the key target areas addressed by the NESTORE project. It is aimed at developing a multi-domain solution for users, able to prolong their functional, social, and cognitive capacity by empowering, stimulating, and unobtrusively monitoring, in other words, "coaching" the user's daily activities according to a well-defined "Active and Healthy Ageing" life-style protocols. Besides the key features of NESTORE in terms of technological solutions, this work focus on the preliminary research carried out in the context of algorithms for modelling and profiling target individuals with the aim of developing an effective dynamic Decision Support System.

Keywords: Decision Support System · Active and Healthy Ageing · User Profiling.

1 Introduction

Ageing population is growing faster in EU [9]. In this context, Information and Communication Technology (ICT) can provide solutions for Active and Healthy Ageing, however, the success of novel ICT solutions depends on the user perception about their efficacy to support health promotion and global wellness. Active and Healthy Ageing represents a complex intervention because it tackles all the human domains: physical, metabolic, cognitive, social, etc. Thus, a multi-domain system needs to be designed to promote proper healthy strategies. The project NESTORE[1] (Novel Empowering Solutions and Technologies for Older

[1] https://nestore-coach.eu/

people to Retain Everyday life activities), funded by EU H2020 programme, has been designed and developed aiming at this integrated vision.

The objective of NESTORE is to develop a virtual companion that, like the mythological Nestor, can give advice to older people so that they can maintain their well-being and their independence at home, based on experience and on understanding the current situation. The experience of NESTORE is based on well-grounded psychological and behavioural theories in conjunction with relevant know-how on the ageing process, while the current user's situation is understood on the basis of a comprehensive system of sensors able to monitor the different key parameters of the user. An intelligent system, deployed on the cloud and leveraging Decision Support (DS) logic delivers "advise and coaching", which is offered via the companion, embodied in a smartphone or an intelligent tangible object, according to the user's preferences and interests. NESTORE provides coaching and personalisation in five crucial domains (called henceforth NESTORE target domains) of the Active Ageing process: i) physiological status; ii) physical activity; iii) social interaction; iv) cognitive and emotional status; v) nutrition.

In this paper, we present the core component behind the coaching activities suggested to the user by NESTORE: an intelligent and innovative Decision Support System (DSS). It is able to analyse the user's behaviour, tracking its changes and its compliance to active ageing guidelines, and providing personalized target behaviours toward the adoption and maintenance of a healthy lifestyle. A DSS can be defined as a computerized information system used to support decision-making in which the characteristics of an individual are matched to a computerized knowledge base [18]. DSS lets users sift through and analyse massive reams of data and compile information that can be used to solve problems and make better decisions. For such a system to work effectively, person's goals, overall cognitive/physical/mental and social status need 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 individualized real-life approach rather than a mere population-based approach based on maximum performance laboratory-based assessments.

The personalisation is built upon dynamic models fed with five well-being dimensions, while the DSS selects, processes, and updates indicators by learning from past choices. In particular, NESTORE implements novel algorithms for detecting and monitoring of important indicators related to user status and behaviour. These algorithms are able to adapt to personal needs, emotional and behavioural patterns, thanks to the inclusion of the well assessed Selection, Optimization and Compensation (SOC) model strategy [15], which provides the methodology for releasing an effective interaction tailored to the current physical, psychological, emotional status of the older person, as captured by the monitoring system.

The algorithm infrastructure comprises unsupervised and semi-supervised algorithms for the inference of user's behavioural profile and the anomaly detection. User's trends in the five well-being dimensions will be described in one

single semantically annotated model giving the possibility of inferring the necessary information to understand the peculiarities of each user among the other users and their self in different scenarios thus generating the appropriate feedback.

The NESTORE DSS is based on a three-layer structure: i) a short-term analysis that analyses data on a daily basis; ii) a long-term analysis that looks at trends and is able to detect change and adapts the coach in the long term, following the changing needs of people as they age; iii) a combined short- and long-term analysis to provide a personalized mix of activities for finally sending personalized plans to the Coach when appropriate. The recognized trends are combined in the DSS with context reasoning to provide robust recommendations and correlations. Behavioural theories leveraging SOC and HAPA [26] models will be embedded in the algorithms. In NESTORE, we will also adopt the so-called "emergent" modelling perspective. With an emergent approach, the focus is on the low-level processing: sensory data are augmented with structure and behaviour, locally encapsulated by autonomous subsystems, which allows an aggregated perception in the environment [5].

The rest of the paper is structured as follows: Section 2 shows the main components of the NESTORE Decision Support System with Section 3 describing its user profiling process. Section 4 illustrates how the profiles are used in the DSS, while Section 5 draws the conclusions.

2 The NESTORE Decision Support System

During recent years, various researches have investigated and developed new solutions in the area of DSS. This is due to the emergence of personalised medicine and the enhanced ability to build tools aimed at predicting personalized risk and advice systems. Currently, most DSSs provide decision support for particular diagnostic or therapeutic tasks such as ensuring accurate diagnosis, improved prognosis and theragnosis, screening for preventable diseases in a timely manner or averting adverse drug events. As regards NESTORE's field of interest, there have been attempts to decision support for telecare but few of these have achieved user-specific personalisation. The current work done in this area can be classified according to their purpose as systems that:

- **Give advice, recommend care plans and trigger alerts.** People at this age require individualised care plans so that they could maintain their health taking into account the idiosyncrasy of each individual. Care plans can give details of dietary requirements, activity levels, targets for physical activity, blood pressure and other tests.
- **Are based on daily life activities.** Changing routines for people in their 60's is not the best way to achieve motivation. That is why it is important to adapt the recommendations to users' current behaviour. In [20], patient's daily life activities, as well as other social elements are used for personalizing their services. In a similar manner, but with different purposes, Croonenborghs et al. [13] proposes to automatically monitor daily activities to detect

abnormal events, like the sudden general absence of activity, or changes in their activities, which would permit an early detection of problems. Likewise, an interesting example to extract daily information is presented in [7], where how TV daily usage can predict mental health change.
- **Extend independent living.** An interesting analysis is made by [8], authors are able to identify with a DSS any sign of transition from healthy to pathological status of elderly people living alone. In a more general manner, [22] demonstrates with a systematic review of current literature that monitoring technologies to detect activities of daily life of elderly people prolong independent living of elderly people.

Most of the DSS analysed before cover only a narrow field of medical knowledge or only part of the relevant factors for preventing the elderly decline are treated and transferred into the DSS. In other words, so far, the inference techniques cannot represent the rich variety of elements that a professional could recommend to a specific person. Furthermore, in the analysed works, due to limitations in the user interface, the advice of DSS relies only on computable input data, which represent just a small proportion of the information required to make decisions. It is extremely difficult for the user to determine whether the input data adequately represent a potential problem. Most of them fail to represent common-sense knowledge and have no real understanding of the user's problem.

In NESTORE, the DSS is intended to help older people to compile useful information about their lifestyle in order to identify proper actions and make decisions to improve or maintain a healthy life. One of the primary objectives in NESTORE project is to develop a DSS so that the users can obtain fast, reliable, personalised, and directly applicable advice. Suggestions are delivered in form of coaching plans, which are divided into pathways composed of different coaching activities and training activities. The DSS and, concretely, a user profiling module will be in charge of proposing the coaching plans and recommendations that better fit each user based on extracted attributes. The information the final NESTORE DSS will use is:

- Models describing the NESTORE target domains;
- Recommendations and guidelines;
- Behavioural models and intervention techniques;
- Existing knowledge from domain experts and other evidence-based sources.

User profiling is one of the key steps in the recommendation processes since it is essential for extracting user characteristics and predicting how much a user will like an item.

As depicted in Figure 1, the user profile and user preferences feed the DSS engine with the necessary inputs to select the most convenient coach plan for each user. In this paper, we focus on the personalisation side of the DSS, mainly embodied in the user profiling component. It describes the way we will profile the users with the final aim of selecting the recommendations and coaching plans that better fit the user.

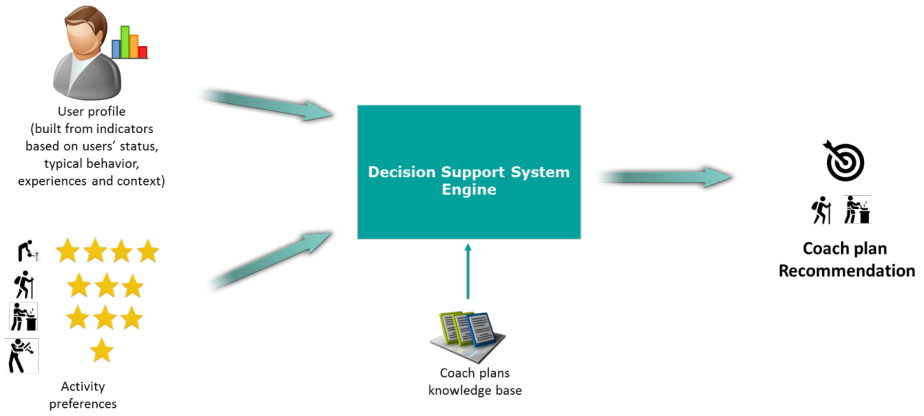

Fig. 1. Conceptual view of the DSS engine.

3 User Profiling

User profiling can be defined as the process of identifying the data about a user interest domain. This information can be leveraged by the DSS to better understand the user needs and, thereby, provide personalized recommendations.

The process to build the user profiling is foreseen as follows:

Step 1. Personas are designed to analyse the different types of information that we will need to personalize NESTORE recommendations.
Step 2. The final set of Personas is analysed and a list of attributes is extracted from it.
Step 3. The list of attributes is complemented with other items that NESTORE domain experts believe that are important for the personalisation procedure.
Step 4. Different user profiling methods are analysed. A twofold user profile is implemented: static and dynamic.
Step 5. The data flow for recommending coaching plans is designed and different use cases where user profiling will be used are envisaged.
Step 6. User profiling module is implemented and integrated in the NESTORE DSS.

3.1 The NESTORE Personas

The Inmates Are Running the Asylum [11] introduced the use of personas as a practical interaction design tool. Personas are hypothetical archetypes of end users. Although they are imaginary, they are defined with significant rigour and precision, and they help to base the potential users' descriptions in real cases to achieve more realism. The main aims of the Persona methodology are:

– to define simple and real personas' profiles in an effective way;

- to create end users' models for representing their life, needs and preferences;
- to build a new understanding about who is the end user to help team members feel connected to them, raise empathy and work with the same personas' cases;
- to work in levels of complexity in function of the depth of definition of each model, for example from expert users to novice and advance their needs and requirements if it is possible;
- to have a model to facilitate discussions in cognitive walkthroughs, storyboarding, role-playing, and other usability activities;
- to create a collection of archetypes to help new team members learn about the characteristics of users' profile.

In NESTORE, the process of creating Personas was based not only on previous research projects prepared for the development of user profiles but also on an iterative process to facilitate the transversal cooperation between the different NESTORE partners and key agents. All this process was based on the importance of reflecting the idiosyncrasies and realities to develop useful profiles for the implementation of the system.

The research was developed consulting the main European demographic public resources to detect the core characteristics of the elderly population, but also to be aware of the possible heterogeneity in this target group. Personas were designed by the co-design experts and piloting countries to include their privileged view of the real users needs and preferences. There were also taken into account the co-design experts considerations to include their privileged view of the real users needs and preferences. Domain experts considerations were also taken into account in order to introduce valuable information to enrich the global understanding of the potential NESTORE users. Another valuable feedback was obtained from the Forum Advisory Stakeholders (FAS). Suggestions and questions pointed out by FAS members were reflected in a new version of users profile and personas document. This fruitful cooperation had, as a result, a large list of profiles (n=24). This contribution aimed to reflect the heterogeneity from the European contest.

Three tools were created to help in the process of refining profiles. Firstly, it was created a checklist with key questions to be asked to co-design experts and pilot teams. The main purpose was to select the final personas systematically and guide experts in the evaluation of each profile to detect those who have more capacity to be more informative or descriptive for technical researchers and developers. Secondly, it was produced a document based on a table with two tabs, one for comparing and grouping the different profiles and a second tab for merging and defining 8 contexts. This tool helped to refine the status, preferences, and attributes. Finally, the third tool was a diagram that presents three important aspects (personal and environmental characteristics and possible pathways). This schema was crucial to highlight the needs and preferences of personas' profiles which will determine the possible elections of pathways of real users. Finally, it was proposed to create a card template to reflect the main char-

acteristics of each profile. This task helps to be systematic and gain consistency to build profiles.

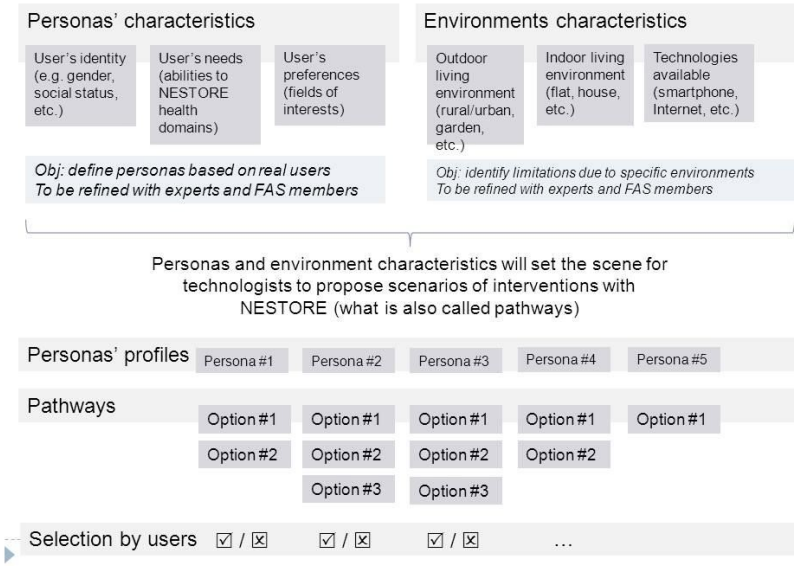

Fig. 2. Diagram of Persona's profile template.

The use of the diagram tool showed in Figure 2 helped to define two main aspects to be included in the refinement of Personas, in accordance with the Cooper definition [10]:

1. *End Goals*: motivational goals but based on their live preferences. These goals could be very effective to determine in some way the final acceptance or user perception of the usefulness of a product or service when it is achieved a convergence between real users' needs and product or service features to answer these needs. When these goals are reflected in profiles, it could help to understand the cognitive walkthroughs, personal contexts or "a day-in-the-life of" scenarios. In the NESTORE case, these goals were defined based on the project domains (physiological, nutrition, cognitive and mental, social interaction).
2. *Life Goals*: defined as the Persona's long-term desires, motivations, self-image attributes and personal aspirations. This description could help to explain why the user is trying to accomplish goals. The previous work developed in NESTORE co-design phase helps to build a better understanding of real-life facts of the elderly population and to add in the descriptions of each profile.

In NESTORE's profiles, it has been suggested indirectly the end goals and life goals by means of the description of personas' daily activities and main interests. For example, in some profiles spending time with family, to be involved in cultural or voluntary movements, etc. Figure 3 provides an example illustrating the building process to define each profile.

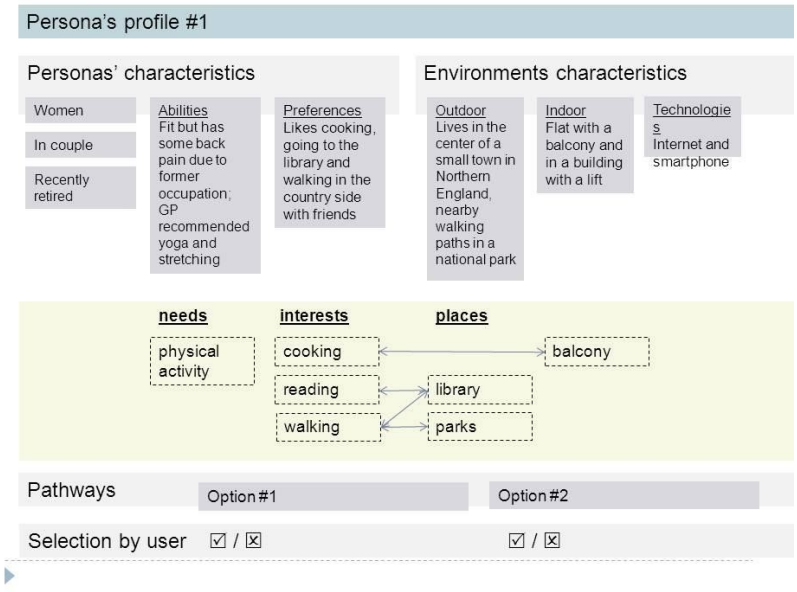

Fig. 3. Diagram of Persona example.

NESTORE's card model includes general information such as gender, age, country or socio-economic status, and more specific details about how many people live in the home, the main characteristics of the living space (size, existence of stairs, balcony or garden), where they live (urban or rural), web connection level, if they have pet or not. Environmental information (weather and humidity that could affect their activities in daily living) is also provided. Finally, Personas' status in relation to the different domains is provided with a level, a definition of the status and target with a narrative description that includes information about preferences and values. Figure 4 shows an example of the cards of NESTORE Personas.

Personas present diversity in relation to the different NESTORE target domains, in order to have a wider spectrum that could enrich the views and understanding of potential needs and preferences of future end users.

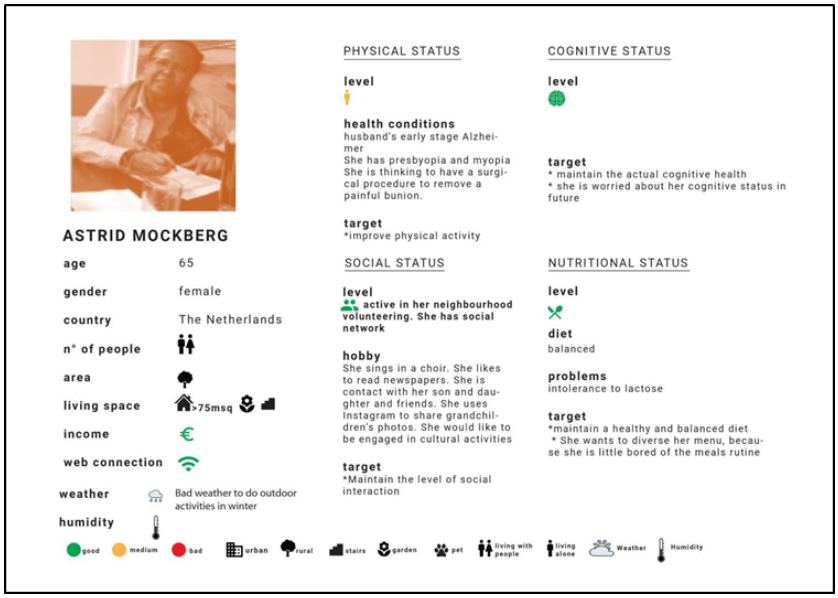

Fig. 4. One of the card from NESTORE Personas.

Physiological status and Physical activity domain Although NESTORE users are defined as healthy older people, it is relevant to include different type of health conditions (not severe chronic diseases) very common and prevalent in the elderly population. There are acute illnesses or health conditions that could determine behaviours or affect system functionalities, and because of this, domain experts pointed out the need to consider some conditions in the health status. Since NESTORE pathways are based on the user needs to maintain or improve a defined physiological status, Personas included profiles with different physical activity levels and several behavioural targets. According to this, Personas have a wide range of physical activity level and profiles with high (2 profiles), medium (5 profiles), and low activity (3 profiles) are included. Similarly, Personas include profiles who need to improve aerobic activities such as walking but do not need stretch exercise as well as aerobically fit subjects who need to increase the frequency of strength activities.

Social interaction domain Personas were defined to describe different living conditions, even though the majority of profiles are characterized by medium or high levels of interaction. Personas are retired or working part-time, or taking care of grandchildren or other family members. Also, there are very active profiles, involved in volunteering activities, hobbies (music, reading, travel, etc.), doing cultural or training activities. But it was decided to also include perceptions of some loneliness in some profiles that could affect the perception of quality of interactions with others. We also defined the use of social networks.

Pathways considered in the social interaction domain were defined to maintain or improve a persons social opportunities or skills.

Cognitive and emotional domain Personas were described to include a broad range of cognitive and emotional status. The majority of profiles (n=7) have a good cognitive status, but they could be worried to maintain it, or they could be worried about future memory loss. Because of this, the personas' profiles have interest in pathways such as: "maintain cognitive skills", "maintain/improve memory" or "maintain/improve daily mental skills". We introduced three profiles with low/medium status that includes: memory loss, depressive symptoms, emotional or mood problems.

Nutrition domain The majority of participants have a well-balanced diet, but they want to improve some aspects as the diversity of menus, introduce some foods and nutrients such as proteins or fibre from vegetables or fruits, or reduce others as cakes, fats, etc. Some of them need to increase the intake of water. Also, it was included two profiles with digestive problems, to help identify other needs and preferences that could affect the diet behaviour or food selections. Two Personas are overweight, but their target was defined to diversify menus and balance their diet because it is possible that in existence of overweight problems the user decides that he/she does not want to reduce body weight or fat mass. However, the NESTORE System will firstly encourage him/her to lose weight (explaining the benefits, risk factors, etc.). If users continue interested in diet, then NESTORE system will understand their needs and preferences in order to propose a pathway that includes some activities which could encourage a behaviour change, if possible. Also, four Personas have a different diet profile because one has food allergies, one has lactose intolerance, and two are vegan or vegetarian in order to introduce some diversification in profiling.

3.2 Static and dynamic profiling

After analysing Personas and complementing the information with domain experts, it is proposed a twofold user profile:

- **Static profile.** It is formed by the status and preferences of the user and it is characterized by containing non-varying attributes. Concretely it includes demographic characteristics, attributes regarding the context where the user lives, physical and physiological aspects 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 (i.e. current weather conditions).

Static profiling is the process of analysing a user's static and predictable characteristics. Users' static features comprehend factual data, such as the idiosyncrasy of their residence (e.g. do they live in a rural or in an urban area?), or their diet routines (e.g. is meat part of their diet?), as well as inter-individual differences in the other NESTORE domains (marital status and perceptions of loneliness, cognitive functioning, physical fitness, etc.). They also describe the environment and context of users. One of the uses of static profiling will be the cluster of users, the resulting groups of which will be inputted into the DSS to make thoughtful recommendations. Considering that real data will not be available until the pilots take off, a data simulator has been implemented to cope with the absence of data creating, thus, solid fundamentals for the clustering process and the recommender system. Getting into detail, the static profile simulator generates a population of users who is described by its fact-based properties.

Dynamic profiling is the process of analysing data coming at run-time from the sensors and applications deployed in the NESTORE user's ecosystem. It describes the changing context of the user, which is the element that leads the personalisation process.

Static features

To build the static profile of a user, not only the three well-known well-being domains (i.e., physiological status and physical activity behaviour, cognitive and social behaviour, and nutrition) need to be considered. The user's context is a quite new feature in user profiling that will help to characterise the situation of the user. There are different types of contexts or contextual information that can be modelled within a user profile [16], but we will focus our attention on the environmental and the demographic context.

After deciding on the obtainable information to profile the users, a collection of variables with the values they can take has been defined. Those have been split per kind of contextual feature (demographic and environmental) and per well-being domain (physiological status and physical activity behaviour, nutrition, cognitive and mental status, and social behaviour). Besides, a category called activities has been added to include the user's routines and preferences. It should be noted that the following variables are not all the properties indicated by the domain experts. This is due to the uncertainty about the setting in the pilots at the current stage and for this reason, some of the variables have been temporarily dismissed since they may not be measurable.

Demographic information is to a great degree relevant to group people according to their culture and generation. Due to the scope of the DSS, there is no need of depicting the participant's culture. Table 1 shows the variables which best characterize users' demographic context.

The environmental context captures the entities that surround the user. These entities can, for instance, be services, temperature, light, humidity, noise, and people [24]. Table 2 displays a compendium of variables that provide contextual information about the environment of users.

Table 1. Demographic variables

VARIABLE	DOMAIN
Age	[65,75]
Gender	F,M

Table 2. Environmental variables

VARIABLE	DOMAIN
Household	Integer
Marital status	Single, couple, divorced, widowed
Living area	Urban, rural
Stairs	Yes, no
Garden	Yes, no
Pet	Yes, no
Employment	Yes, no
Facilities nearby	Beach, theatre, etc.

Routine activities of users, as well as their preferences, should be taken into account to provide personalized recommendations that adapt to their lifestyle. The variables that will be considered are shown in Table 3.

Table 3. Variables related to routine activities

VARIABLE	DOMAIN
Physical activity duration [min]	less than 30; [30,60]; [61,120]; more than 120
Physical activity frequency	Daily, 2-3 times per week; weekly
Preferences	Walk, bike, swim, golf, dance, extreme sport, etc.

The factual data that best describes the physiological status of users mainly comes from their anthropometric characteristics, presented in Table 4.

The nutritional domain will basically be characterized by the dynamic profile. Only the list of refused foods will be considered to create the nutritional static profile, as it is presented in Table 5.

The variables that describe the cognitive and mental status of users can be found in Table 6.

Finally, the static social integration level can be characterized by the factual information contained in Table 7.

Dynamic features: short- and long-term indicators

Various sensors and applications deployed in the NESTORE platform generate, at run-time, input data to the DSS. An environmental monitoring system is

Table 4. Variables related to the physiological status

VARIABLE	DOMAIN
Level	Low [0,33]; medium [34,66]; high [67,100]
Aerobic fitness level	To improve [0,19]; to retain [20,30]
Strength level	To improve [0,35]; to retain [36,50]
Flexibility level	To improve [0,5]: to retain [6,10]
Balance level	To improve [0,5]; to retain [6,10]
Body height	[m]
Body weight	[kg]
Body mass index (BMI)	[kg/m^2]
Fat mass	[%]
Fat-free mass	[%]

Table 5. Variables related to the nutritional domain

VARIABLE	DOMAIN
Refused foods	Text

Table 6. Variables related to the cognitive, social, and mental status

VARIABLE	DOMAIN
Level	Good; medium; low
Status	Positive and negative affect; life satisfaction; depressive symptoms; cognitive functioning (test-based); memory failures (self-reported); loneliness; social integration

Table 7. Variables related to social behaviour

VARIABLE	DOMAIN
Level	Good; medium; low
Company	Friends; volunteering/working; family
Frequency	Daily; 2-3 times per week; weekly; monthly; yearly
Community	Friends; association; activism; volunteer

deployed in the NESTORE user environment as an ensemble of wireless sensors able to sense the variables indicated by the domain experts in the relative NESTORE target domains. Furthermore, it has the aim of detecting the interaction of the user with the environment and monitoring the status of the environment itself (e.g., indoor air quality). Also, an innovative wearable device is expected to be worn by the NESTORE user. It is able to detect physiological parameters (e.g., heart rate, steps, distance, sedentariness, stairs, energy expenditure, etc) while the user performs the activities suggested by the NESTORE virtual coach.

Reflecting the separation of concerns of all the data generator deployed in the NESTORE environment, we call *environmental* device any sensor deployed in the user's vital space, while *wearable* the device worn by the user during his daily activities. As a further source of information about the user's status, we have derived data as result of a computation or fusing strategy and data coming from a direct input of the user, as questionnaires while interacting with the NESTORE coach. We call the latter *soft data*. Table 8 describes how the device types (*wearable*, *environmental*, and *soft data*) cover the variables indicated as needed by domain experts for each NESTORE target domain.

Table 8. Relationships between device types and domains variables

NESTORE DOMAIN	VARIABLES	DEVICE TYPE
Physical Activity	Physical Activity Behaviour Cardiorespiratory Exercise Capacity Cardiovascular System Respiratory System	Wearable
	Strength-Balance-Flexibility Exercise Capacity Anthropometric Characteristics Musculoskeletal System Sleep Quality	Environmental
Nutrition	Energy Expenditure Nutrition Habits	Soft Data
Cognitive, Mental, Social	Cognitive Status Mental Status Mental Behaviour and States	
	Social Behaviour	Environmental

From the devices point of view, besides the wearable device, in the form of a smart wristband, we plan to deploy a smart scale to collect anthropometric, musculoskeletal characteristics and balance [2] and a ballistocardiographic system in order to perform sleep monitoring [19, 12, 1]. For social behaviour, we will use Bluetooth Low Energy (BLE) beacons to detect social interactions among NESTORE users and their relatives (bringing with them keyfobs equipped with mobile BLE tags) with their duration, function, location, and number. We will exploit the capability of calculating the proximity between BLE devices from Re-

ceived Signal Strenght Indicators (RSSIs) [6, 4] also for detecting the interaction of the user with the pieces of furniture in the house on which fixed beacons are deployed, giving us insights on the users level of sedentariness [21]. The possibilities offered by BLE beacons of customizing their hardware and firmware will allow us to advertise, from fixed beacons, additional information like motion (to increase the level of accuracy in detecting interactions with point of interests in the house) and temperature and humidity (to calculate the indoor air quality indicator [23]).

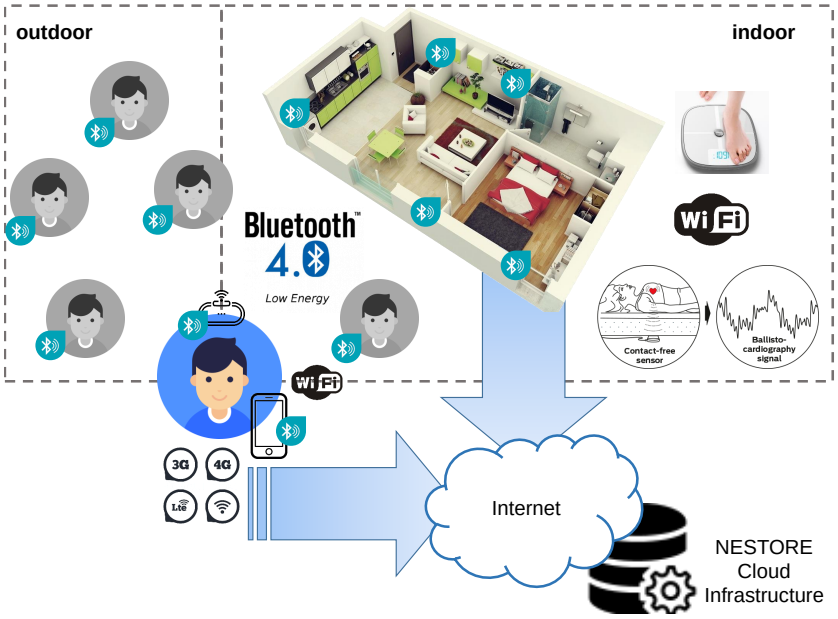

Fig. 5. The WoT approach for environmental and wearable devices

From the architectural and deployment point of view, in order to reduce the effort needed by the end user to install and use the environmental sensors, we chose to adopt a Web of Things (WoT) approach. WoT is a computing concept that describes an environment where everyday objects are fully integrated with the Web. The prerequisite for WoT is for the "things" to have embedded computer systems that enable communication with the Web. Such smart devices would then be able to communicate with each other using existing Web standards. Considered a subset of the Internet of Things (IoT), WoT focuses on software standards and frameworks such as REST, HTTP and URIs to create applications and services that combine and interact with a variety of network devices. The key point is that this doesn't involve the development of new communication paradigms because existing standards are used [17, 14, 3]. Figure 5 shows the adopted WoT approach for environmental and wearable devices.

4 Data flow for recommending coaching plans

A general workflow illustrating how the two types of the previously described profiles are used in the DSS is depicted in Figure 6. As shown in the picture, we foresee to generate clusters or groups of users taking into account a number of static profiles generated with the simulator described in Section 3.2. Afterwards, experts will select the best type of coaching activities to be recommended to each group.

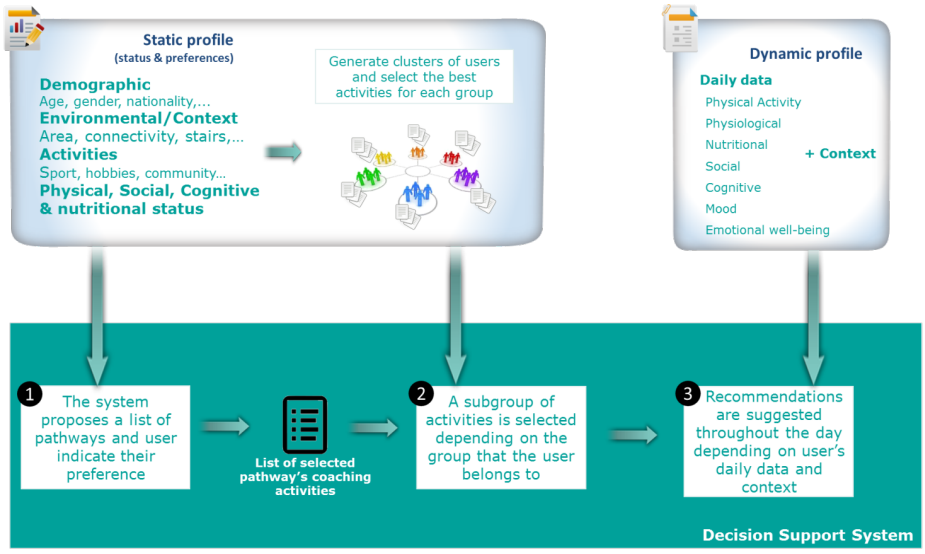

Fig. 6. Data flow for recommending coaching plans

The recommendation process carried out in the DSS will follow the Health Action Process Approach (HAPA) model [25]. In this paper, we summarize the DSS personalization process in three main steps based on the phases described in the HAPA model and the three levels of coaching of NESTORE:

Step 1. After acquiring the needed information about the user for building their static profile (around 2 weeks), the system proposes a list of pathways that correspond to the detected weaker aspects (this is the result of the phases 1 and 2 of the HAPA model). The user selects one of the pathways to focus during the following weeks (this corresponds to phase 3 of the HAPA model).

Step 2. Each pathway has a predefined list of coaching activities, but not all of them apply to all the users. In this step, the DSS selects the subset of coaching activities that better fit the group where the user belongs to.

Step 3. Training activities or recommendations related to the different chosen coaching activities are suggested to the user depending on the dynamic

profile data. The user, finally decides which activities he wants to perform.

In the following, we explain all the steps with a concrete example.

After two weeks gathering information about the user through the sensing system and the coach, the profiler module in the DSS constructs the static profile shown in Table 9. It contains the necessary information to characterize the base-

Table 9. Static profile example

Demographic	Age	*67*
	Gender	*Female*
Environmental	Household	*1*
	Marital status	*Widowed*
	Living area	*Urban*
	Pet	*Dog*
	Stairs	*Yes*
	[...]	
Activities	Hobbies	*Cooking*
	Sport preference	*Walk, dance*
	Physical activity duration (average)	*<30 min.*
	Physical activity frequency (average)	*2-3 times per week*
	[...]	
Physical Activity (baseline)	Aerobic Fitness Level	*10/30*
	Strength Level	*5/50*
	Flexibility Level	*6/10*
	Balance Level	*4/10*
	Total PA Level	*25/100 (Low)*
	[...]	
Nutrition (baseline)	Refused foods	*Citric fruits*
Cognitive (baseline)	(Objective) Performance level	*Medium*
	Self-reported cognitive failures	*Some*
	[...]	
Social (baseline)	Loneliness	*Low*
	Social network contacts and social integration	*Medium*
	Frequency	*Friends (1 per week), Family (2-3 times per week)*

line of the user in different general aspects and in all NESTORE's domains of

interest. This information allows the system to infer which pathways to propose and which groups does the user belong to.

Let's say that the example user belongs to group A. The system could interpret that the weakest points are physical activity and social domains, so it proposes the following pathways:

- Improve fitness level
- Improve social activities
- Retain healthy eating
- Retain memory

Assuming that the user selects "Improve fitness level" as their main objective, the DSS takes the subset of activities of group A that belongs to this pathway and some other activities from the other pathways (step 2). For example:

- Climb stairs (2 floors)
- Track your steps
- Nordic walk
- Walk on the beach
- Track your nutrition
- Cook new recipes

Then, the coaching phase starts. The DSS creates on a daily or weekly basis a dynamic profile that will permit to personalize and contextualize the recommendations even more. An example of a dynamic profile is listed in Table 10.

Table 10. Dynamic profile example

Daily/weekly data	Total PA Level	*Low*
	Nutrition level	*Low calcium intake*
	[...]	
Context	Location	*Barcelona*
	Weather	*Sunny, 26°*
	[...]	

The activities and recommendations proposed to the user throughout the day could be:

- (At 8:30) *Add more milk to your morning coffee!*
- *Today its sunny, why dont you go for a walk on the beach?*
- (Afternoon) *Go for a nice long walk with your dog!*

Finally, the user can decide which activity he wants to perform.

5 Conclusions

The NESTORE project addresses five important domain affecting their active and healthy ageing trajectories: physiological status and physical activity, social interaction, cognitive and emotional status, and nutrition. This is achieved by designing a multi-domain solution aimed at coaching older people toward an active and healthy ageing lifestyle protocol.

We presented the core component behind the coaching activities suggested by NESTORE: an intelligent and innovative Decision Support System. It is able to analyse the user's behaviour, tracking its changes and its compliance to active ageing guidelines, and providing personalized target behaviours for the adoption and maintenance of a healthy lifestyle.

The system is going to be deployed and validated in 60 pilot sites across Europe during the next year. At the current stage of the project, the overall system is under development leveraging the extensive research carried out in the context of algorithms for modelling and profile the target users. The output of this process represents the core focus of the paper.

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