e-VITA Use Cases Configurator: A Tool to Identify the Optimal Configuration of the Sensor Network and Coaching Devices to Enable Older People to Age Well at Home

DOI: 10.1109/MetroLivEnv56897.2023.10164067

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Abstract: This paper describes the development and functionalities of the Use Cases Configurator, a tool developed within the e-VITA project to identify the optimal configuration of the sensor network and coaching devices based on older users' needs and requirements, considering the indoor environmental setting and the minimization of costs without losing measurement accuracy. The software is designed to be used by the technology platform installers and caregivers to enable older people to age well in their homes or care organizations by providing them with a personalized service tailored to their needs, preferences and culture.

I. INTRODUCTION

The growing ageing population in recent years has led to a rapid development of sensing technologies within older peoples' living environment. Smart living solutions are increasingly being designed and implemented in a connected way, supporting the Smart Home concept. In general, a smart home is equipped with different types of sensors that monitor physiological signals and track the activities of the older user's daily life to provide the user with assisted, safe and comfortable living, for example through embedded sensors for fall detection and prevention. Hence, new, innovative and tailored prevention solutions are needed to support the care and well-being of older people. The e-VITA project "EU- Japan Virtual Coach for Smart Ageing" (H2020-SC1-DTH- 04) presents an innovative virtual coaching approach that addresses the domains of Active and Healthy Ageing (AHA) and Active and Assisted Living (AAL) in terms of cognition, physical activity, mobility, mood, social interaction, leisure, and spirituality, with the aim of empowering older people to better manage their health and daily activities, resulting in improved well-being and stakeholder collaboration [1], [2].

The e-VITA virtual coach offers personalized recommendations based on the analysis of data collected from wearable devices and non-intrusive sensors placed in the smart living environment [3] and provides support through natural language interaction with holograms, emotional objects or robots [4]. Given the state-of-the-art lack of systems and tools to customize this network of sensors and coaching devices for each user, the aim of the present work was to develop a tool that would meet these demands, named Use Cases Configurator (UCC). As discussed in [5], installations in homes cannot always be done in the same way, so having a tool to determine exactly what to install according to the characteristics of the user and the environment is very useful to reduce redundant installations, avoid unneeded expenses and prevent negative feedback from users. Cultural aspects play an important role in making decisions on which technologies the end user prefers to use. Cultural environment and religion are indeed aspects to consider when choosing a coaching device: there is a considerable difference between Europe and Japan, less so within European countries. Thus, the newly developed tool not only includes an intelligent component in the optimization process of the sensor network by means of Machine Learning (ML) algorithms, but also considers cultural aspects relating to the end user (such as country of origin and religion).

The paper is structured as follows: Section II presents the Use Cases Configurator and describes the sensors and coaching devices included in the tool to measure users' behaviour, emotions and physiological parameters and to provide them with coaching services. In Section II, the chapters Design (A), Development (B) and Results (C) describe the relevant development phases of the tool. Chapter A explains the reason that prompted the authors to develop the configurator and illustrates the idea behind it. Chapter B, with sub-chapters Sensors and Coaching Devices Configurations and Validation, gives some technical insights on the implementation of the tool. Chapter C shows the main interfaces and functionalities of the configurator. Section III closes the document with conclusions.

II. USE CASES CONFIGURATOR

To enable users to have a system tailored to their needs and preferences, and at the same time to optimize the sensor network configuration, the UCC tool was developed in the project. The UCC is a software component of the e-VITA platform. The role of the UCC is to offer to technical installers and formal caregivers an interface that allows to translate the preferences, needs and goals that the end user expects to achieve, in the optimal configuration of the sensor network and coaching devices to be installed.

The UCC considers a set of sensors and coaching devices to be installed in the home of the older users to meet the use cases of the project.

The sensing technologies identified (Table I) to measure users' behaviour, emotions and physiological parameters fall into three categories: user-related devices, which are worn by the user and aim to sense physiological parameters; environmental devices, which measure physical quantities useful for assessing the comfort level and the Indoor Environmental Quality (IEQ); and home-based devices, installed in the home to monitor the user's behaviour and activities. It is worth noting that the unavailability of some sensors on the Japanese market has forced to extend the list of devices that make up the platform.

Table I. Sensing Technologies

Type	Name	Description	Data
Environmental devices	NETATMO Smart Indoor Air Quality Monitor 	Smart device that measures indoor environmentalparameters. → *for Europe*	Temperature (°C)Humidity (%) Noise (dB) CO_2 (ppm)
	EnOcean ETB-RHT 	Smart device that measures indoor environmentalparameters. → *for Japan*	Temperature (°C)Humidity (%)
Home-based devices	DELTA DORE DMB TYXAL+ 	Device for monitoring the home environmentand the user behaviour. → *for Europe*	Smart motion sensor that provides ON/OFFstate upon detection ofuser motion.
	DELTA DORE DO TYXAL+ 	Device for monitoring the home environmentand the user behaviour. → *for Europe*	Smart sensor providingON/OFF state upon detection of door opening/closing.
	EnOcean ETC-PIR 	Device for monitoring the home environmentand the user behaviour. → *for Japan*	Smart motion sensor that provides ON/OFFstate upon detection ofuser motion.
	EnOcean ETB-OCS 	Device for monitoring the home environmentand the userbehaviour. → *for Japan*	Smart sensor providingON/OFF state upon detection of door opening/closing.

User-related devices	OURA Ring 	Smart ring device that tracks sleep patterns and physiologicalparameters of the user.	HR (bpm)HRV (ms) Respiratory rate (rpm)Sleep timing (h) Burned calories Steps Inactivity time (h)
	HUAWEI Band 7 	Wristband that tracks physiological parameters ofthe user.	HR (bpm)HRV (ms)SpO2 (%) Body temperature (°C)Activity level (index) Steps Burned calories Sleep duration (h) Sleep quality (index)
	NEU XB-01 	Compact device that measures brain activity of the user while worn onthe forehead.	Brain activity (index)
	uSkin pillow 	Smart pillow that monitors sleep parameters bymeans of built-in forcesensors.	Sleep duration (h) Sleep quality (index)

The coaching devices identified (Table II) are: NAO robot, a small humanoid robot commonly used for human-robot interaction studies [6]; Gatebox hologram, which provides visualization of a virtual coach using a 3D effect; DarumaTO [7], a social robot resembling a traditional Buddhist and Shinto doll called Daruma; CelesTE, an interactive small angel statue intended as a prayer companion for Christian Catholic older people designed on the idea of the pre-existing SanTO robot [8], [9]; and Google devices, namely the Nest Mini, a smart speaker, and the Nest Hub, a smart speaker withbuilt-in display.

Table II. Coaching Devices

Name	**Description**
NAO robot 	Softbank NAO humanoid interactive mobile robot that allows multimodal natural language interaction and autonomous movement.
CelesTE 	Prayer companion designed for Christian Catholic users. It tells the story of today's saint, reads the Bible, answers by citing a quote, a verse of the Bible, a prayer, and it prays together in turns. The communication is based on speech, movement, touch, and lights.
DarumaTO 	Social companion robot designed for Japanese and Chinese users. It provides printed reminders and interacts with the uservia speech and touch sensing.

Gatebox 	Hologram like device that projects characters with which the user can interact. Internal sensors such as a camera and a microphone allow the user to converse with the projected character. It connects to the Internet via a wireless LAN. With infrared rays and Bluetooth, it can also be connectedto household appliances and other devices.
Google smart speakers  Google Nest Mini 2nd Gen (without screen)  Google Nest Hub 2nd Gen (with screen)	Smart speaker with Google vocal assistant. The choice of device type is left to the end user: - device with screen and speaker (Google Nest Hub) - device with only speaker(Google Nest Mini) The interaction takes place between the user and the Google Assistant built in the device, which forwards the requests to the e-VITA Dialogue Manager, so that the response is processed by the e-VITA virtual coach.

A. *Design*

The necessity to identify the sensor network and coaching devices according to the user's needs and requirements lead to the development of the UCC. The UCC was designed as a simple and user-friendly Graphical User Interface (GUI) to meet the needs of platform installers, technicians and caregivers.

Fig. 1 shows the idea at the base of the configurator: focusing on creating a smart living environment suitable for older people, the UCC considers not only their preferences, but also the minimization of costs and the number of sensors without losing measurement accuracy. In this way, users have a service tailored to their needs and preferences. Optimizing the sensor network avoids negative feedback from users in relation to the use of multiple sensors and allows for a low implementation cost.

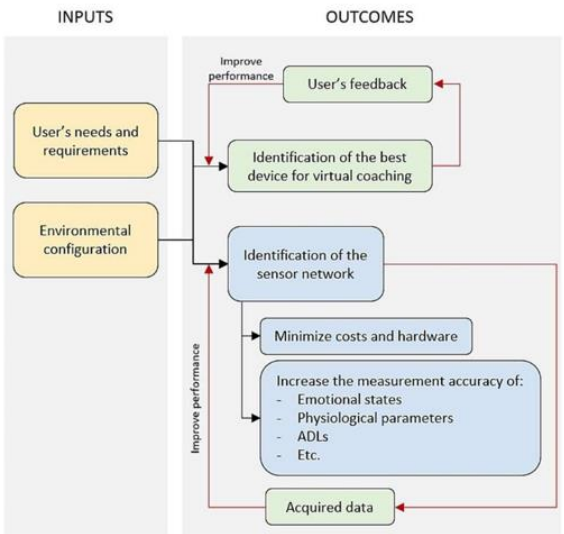

Fig. 1. Use Cases Configurator conceptual diagram.

B. *Development*

The UCC is developed in Python language as a GUI to obtain information on which sensors and coaching devices will constitute the system from information, preferences and goals of the end user. The inputs of the configurator are the needs, requirements and goals of older people arising from use cases defined within the project, information about the living environment (rooms of the house), sensors acceptance (wearables, non-invasive sensors) and personal information (age, gender, religion, etc.).

1) *Sensors and Coaching Devices Configurations*

Data are processed by the configurator in such a way as to provide the configuration of the sensor network for the specific use case as well as identify the best device for virtual coaching. Sensing technologies and coaching devices are thus classified based on inputs (meaning that specific outputs will occur upon the occurrence of a certain condition, given by the choices made by selecting the options or by information entered in the UCC input interface), to provide a complete and integrated sensor network capable of identifying user behaviours, physiological states and emotions and define a coaching device accepted by the end user.

Table III shows the sensors, coaching devices and applications associated with each of the goals of the use case domains considered in the UCC.

Table III. Technologies related to the use case goal

Goal	Sensors	Coaching devices	App
Monitoring: Monitoring the home environment and user habits.	Delta Dore motion sensors (EU), EnOcean motion sensors (JPN) Netatmo air monitor (EU), EnOcean air monitor (JPN)	NAO, Gatebox, Google smart speaker	-
Physical training andfall prevention: *Physical training to improve resistance, posture, balance and muscle strength.*	Huawei Band7, Oura Ring	NAO, Gatebox, Google smart speaker	Exercisechatbot
Mobility outside: *Sportsand activities with local communities.*	Huawei Band7, Oura Ring	-	Exercisechatbot
Walking everyday: *Walk for 30 min at day.*	Huawei Band7, Oura Ring	-	Exercisechatbot
Support to psychological well- being: *Improvement of overall psychological well-being, self-efficacy.*	Huawei Band7, Oura Ring	NAO, Gatebox, Google smart speaker	-
Emotional recognition:*Improvement of overall psychological well- being, mood.*	-	NAO, Gatebox,Google smart speaker	-
Foster social relationship: *Improvement of social connectedness.*	-	NAO, Gatebox,Google smart speaker	Social platform
Support cognitive functions: *Improvement/stability of memory, attention, orientation and executive functions.*	NEU XB-01	NAO, Gatebox,Google smart speaker	ABC App
Supporting healthy eating: *Improvement ofhealthy eating habits.*	-	NAO, Gatebox,Google smart speaker	Nutritionchatbot
Weight loss and BMI reduction: *Personalized diet, BMI reduction.*	-	NAO, Gatebox,Google smart speaker	Nutritionchatbot Exercisechatbot
Spirituality: *Comfort/wise words,tales, stories.*	-	DarumaTO(EU), CelesTE(JPN)	-

2) Validation

The rule-based algorithm that associates inputs with outputs (sensors, coaching devices) considers the results of preliminary studies conducted on older adults and has been updated following feedback from living lab tests and the pilot study conducted in Italy, Germany and Japan.

The UCC will be validated with large-scale use during the six-month Proof-of-Concept study starting in June 2023.

C. Results

Fig. 2 shows the UCC input screen through which it is possible to enter information and select options regarding the end user and the home environment. First of all, there are general end user information (age, gender, country, religion, living situation). Cultural aspects play an important role in making decisions on outputs. Cultural environment and religion are indeed aspects to consider when choosing a coaching device: DarumaTO is mainly used in Japan or at least for Shinto and Buddhist end users, while CelesTE is designed for Christian end users who want a spiritual companion; other devices such as Gatebox, NAO and Google smart speakers are used regardless of religion and culture but based on user preferences. The living situation refers to the residents living in the home. In fact, the older user may live in multi-resident contexts, e.g. husband-wife couple. The UCC thus stores this information, which is considered when processing the data acquired via the installed motion sensor network [10]. The environmental setting also affects the sensor network configuration, i.e., the number and type of sensors that needs be installed. The UCC requires to specify which rooms make up the house and to provide their number. To ensure better user acceptability without losing measurement accuracy, the UCC follows the methodology we proposed in [11], which allows to optimize the configuration of the motion and door sensor network by simulating human activities, and thus sensor activations, in the reconstructed environment using a simulator and by analyzing the datasets generated using ML algorithms to classify Activities of DailyLiving (ADL).

User preferences entered in the UCC cover the use of wearable sensors and stationary sensors. Indeed, the end user may or may not be inclined to use wearable sensors or to install sensors in the home. Based on a yes/no answer, the UCC considers the use or non-use of these sensors in the configuration of the sensor network. Users can choose to use either a smartphone or a tablet, depending on their preferences, as a support device for managing and configuring the virtual coach and for using the several services andapplications.

Fig. 2. Use Cases Configurator input interface.

Fig. 3 shows an example of sensor network for the “Cognitive training” use case related to the Health coaching domain (use of the e-VITA platform to provide educational material, guidance and coaching for health-related topics such as physicality, nutrition, cognition and psychological health). The UCC, choosing from available technologies and considering the results of sensor network optimisation, identifies the appropriate set of sensing and coaching devices to acquire data and provide proper services to achieve the user's goal. In this case, the devices selected are the NEU XB- 01 (and its ABC App for cognitive training), the smartphone (support device) needed to run the ABC App, and as coaching devices the Gatebox, NAO and Google smart speaker. The type of coaching device is left to the end users according to their preferences and the cost of the selected configuration, which is indicated in output by the UCC.

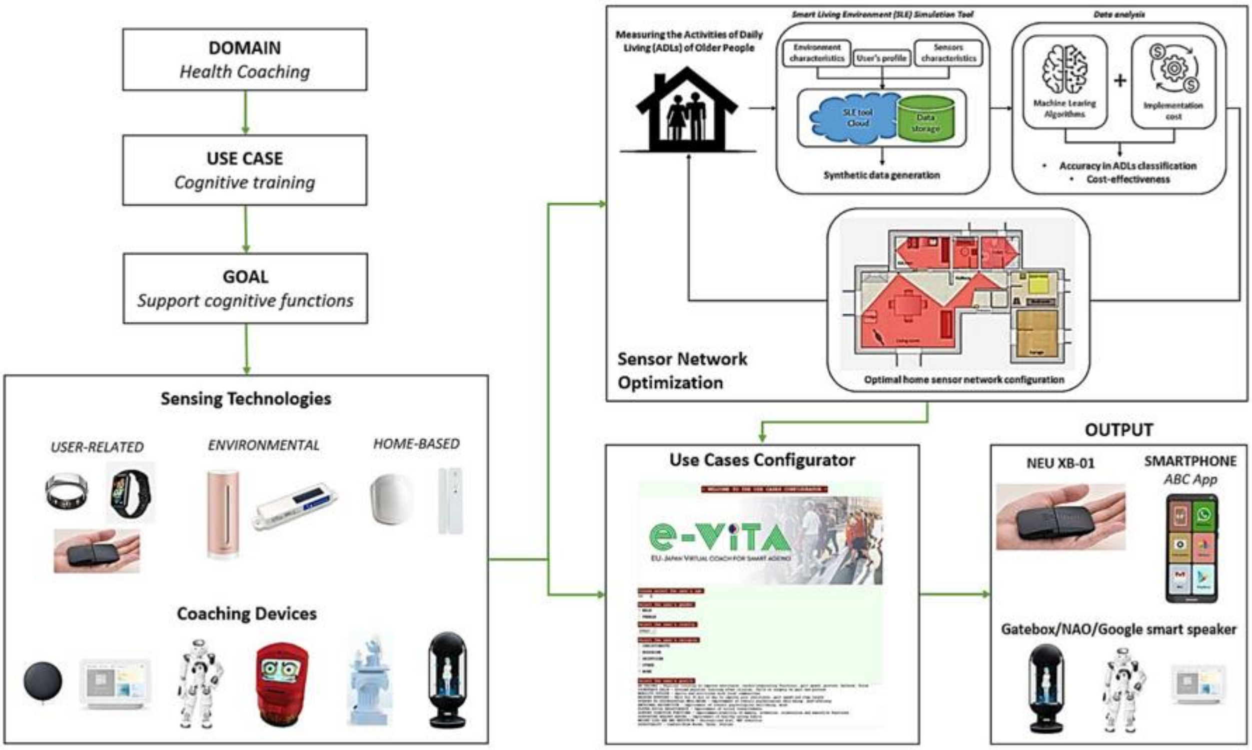

Fig. 3. Example of sensor network and coaching devices identification for Cognitive training use case of the Health coaching domain.

Fig. 4 shows the output provided by the UCC for the above example of sensor network identification for the "Cognitive training" use case.

Fig. 4. Use Cases Configurator output screen.

The UCC output consists of five areas:

1. *Selected goals*, showing the goals selected during the input phase based on end user's preferences.
2. *Recommended Apps*, which show applications and services that can help the end user achieve his/her goal or that are necessary for the proper functioning of specific devices
3. *Recommended installation*, showing the optimal sensor network selected by the UCC according to the use case. The sensor network indicated by the configurator consists of:
   - support device
   - coaching device
   - sensors (static and/or wearable devices)
4. *Setup options*, showing the available configurations of the sensor and coaching device platform and their costs. In this way, the user can select the configuration to be used according to the expense he or she wishes to incur. The intention is to adapt the network of sensors and coaching devices to the needs and possibilities of the user, who may in fact be reluctant to use very expensive devices.
5. *Installation tips*, in the form of clickable buttons for each of the e-VITA platform’s sensor and coaching devices, provide advice to the technician on the installation.

III. CONCLUSIONS

This paper presents the Use Cases Configurator, a software component of the e-VITA system designed to be used by the platform’s technical installers, pilot implementers, formal caregivers to identify the optimal configuration of the sensor network and coaching devices to be installed inside the older people's home. This tool allows to optimize the configuration of sensing technology and coaching devices based on users’ needs and requirements, also considering the indoor living environment setting and cost minimization without losing measurement accuracy. Sensing technologies and coaching devices are thus classified based on inputs, to provide a complete and integrated sensor network capable of identifying user behaviours, physiological states and emotions and identify a coaching device accepted by the end user.

The use of the configurator facilitates the implementation of sensing technologies and coaching devices (such as robots) that provide support and services to older people within the smart home or in care organizations, helping the designer in the process of identifying the most suitable sensor network for the user's needs and preferences, the indoor environment and the costs to be incurred.

ACKNOWLEDGMENT

Thanks to the members of the e-VITA project financed by the European Union H2020 Program under grant agreement No. 101016453 and in Japan by the Ministry of Internal Affairs and Communications (MIC) under grant agreement No. JPJ000595.

REFERENCES

1. J. Möller et al., ‘User Perceptions and Needs Analysis of a Virtual Coach for Active and Healthy Ageing—An International Qualitative Study’, International Journal of Environmental Research and Public Health, vol. 19, no. 16, Art. no. 16, Jan. 2022, doi: 10.3390/ijerph191610341.
2. M. McTear et al., ‘Empowering Well-Being Through Conversational Coaching for Active and Healthy Ageing’, in Participative Urban Health and Healthy Aging in the Age of AI, Cham, 2022, pp. 257–265. doi: 10.1007/978-3-031-09593-1_21.
3. S. Casaccia, K. Jokinen, R. Naccarelli, and G. M. Revel, ‘Well-being and comfort of ageing people based on indoor environmental conditions: preliminary study on human-coach conversation’, in 2022 IEEE International Workshop on Metrology for Living Environment (MetroLivEn), May 2022, pp. 164–169. doi: 10.1109/MetroLivEnv54405.2022.9826905.
4. K. Jokinen, K. Homma, Y. Matsumoto, and K. Fukuda, ‘Integration and Interaction of Trustworthy AI in a Virtual Coach – An Overview of EU-Japan Collaboration on Eldercare’, in Advances in Artificial Intelligence, Cham, 2022, pp. 190–200. doi: 10.1007/978-3-030- 96451-1_17.
5. S. Casaccia et al., ‘Health@Home: pilot cases and preliminary results : Integrated residential sensor network to promote the active aging of real users’, in 2018 IEEE International Symposium on Medical Measurements and Applications (MeMeA), Jun. 2018, pp. 1–6. doi: 10.1109/MeMeA.2018.8438630.
6. R. Browne, T. Ogawa, J. Vizcarra, and K. Jokinen, ‘Experiments on the Nao Robot as a Virtual Coach’, 人工知能学会全国大会論文集, vol. JSAI2022, p. 3S4IS404-3S4IS404, 2022, doi: 10.11517/pjsai.JSAI2022.0_3S4IS404.
7. G. Trovato *et al.*, ‘The creation of DarumaTO: a social companion robot for Buddhist/Shinto elderlies’, in *2019 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)*, Jul. 2019, pp. 606–611. doi: 10.1109/AIM.2019.8868736.
8. G. Trovato, C. Lucho, A. Ramón, R. Ramirez, L. Rodriguez, and F. Cuellar, ‘The creation of SanTO: a robot with “divine” features’, in *2018 15th International Conference on Ubiquitous Robots (UR)*, Jun. 2018, pp. 437–442. doi: 10.1109/URAI.2018.8442207.
9. G. Trovato *et al.*, ‘Communicating with SanTO – the first Catholic robot’, in *2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*, Oct. 2019, pp. 1–6. doi: 10.1109/RO-MAN46459.2019.8956250.
10. R. Naccarelli, S. Casaccia, and G. Revel, ‘The Problem of Monitoring Activities of Older People in Multi-Resident Scenarios: An Innovative and Non-Invasive Measurement System Based on Wearables and PIR Sensors’, *Sensors*, vol. 22, p. 3472, May 2022, doi: 10.3390/s22093472.
11. R. Naccarelli, S. Casaccia, M. Pirozzi, and G. M. Revel, ‘Using a Smart Living Environment Simulation Tool and Machine Learning to Optimize the Home Sensor Network Configuration for Measuring the Activities of Daily Living of Older People’, *Buildings*, vol. 12, no. 12, Art. no. 12, Dec. 2022, doi: 10.3390/buildings12122213.