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ASSISTO eCARE 4.0 – An IoT- and AI-based architecture for assisted active aging

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Abstract

INTRODUCTION: All over Europe, there is an increasing demand for social/welfare services and a shift towards a demand increasingly formed by a mix of well-being and safety. Artificial intelligence (AI), Internet-of-Things (IoT) and cloud computing techniologies can play a major role in such a type of services.
OBJECTIVES: The aim of this work was to investigate, design, develop and validate a prototype platform, named Assisto eCare 4.0, providing "well-being" and "safety" services/functionalities to home elderly residents.
METHODS: The platform builds upon biometric technologies and analytics functionalities exploiting AI techniques in order to limit human intervention during emergencies and automatically and immediately deciding actions to be performed by making the operators intervene also directly at the user home.
RESULTS: The prototype has been validated with a group of 22 users over a period of more than 7 months. The results derived from the final evaluation questionnaire show that the majority of participants rated the service as excellent.
CONCLUSIONS: The platform has been released according to the API-as-a-Service model, proposing itself with a pioneering model of social open innovation, which is to develop and test the IT system and then to make it available to all those who want to use it. Currently (July 2021) the system has been engineered and offered by a consortium of different industries and is operative in the Rome area.

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1. Introduction

The progressive aging of population all over Europe has created an increasing demand for novel services. In particular, starting from interviews on a sample of users over 65, we have focused that the question is not so much about more traditional "health" services, but more about "well-being" and "safety". In other words, what users are asking nowadays is to be able to continue to carry out their life, their sports and hobbies, etc. but with some kind of control that can automatically activate help procedures in case of need.

On the basis of this, the Sempre Vicini[1] project has investigated, designed, developed and validated an Internet-of-Things (IoT) architecture, which receives data about the users from biometric devices for both domestic/indoor use and for external/outside use (via a smartwatch) and that transmits them to a cloud platform. Algorithms and techniques based on Artificial Intelligence (AI) have been integrated into the platform in order to customize the system on individual users and habits. The platform, named Assisto[2] eCare 4.0, via biometric technologies and home automation, monitors the person and stimulates her to take care of herself. Biometric bracelets and sensors constantly

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[1]In Italian, "sempre vicini" means "always close", to give the feeling of being always around, just as a relative person.
[2]In Italian "assisto" means "I take care".

monitor vital parameters (pressure, heart rate, temperature, position, fall, etc.), stimulates the user to follow a healthy lifestyle, offer 24-hour automated control for safety and emergency management if the biometric values exceed safety thresholds or there are other problems inside or outside the home. The system is equipped with AI-based techniques limiting human intervention during emergencies and automatically and immediately deciding actions to be performed by making the operators intervene also directly at the user home.

In terms of business model, Assisto eCare 4.0 has been thought as a complete service, to be sold at an average price equal to that of a TV subscription; it can be sold by social cooperatives, telco, utilities, pharmacy networks, insurance companies, and preliminary market studies convinced that there is a market for this. Notably the platform/service is able to promote "new jobs" by pushing persons to work with these new biometric technologies in order to create the new professional figure of "social worker 4.0".

The aim of this paper is to outline the technical architecture of the system, and the process adopted for its realization and preliminary validation. We review in Section 2 relevant initiatives and related work, then we describe in Section 3 the medical background and assumptions leading to the system. The Sections 4, 5, and 6 are focused on the main technical aspects, describing functionalities, architecture and the usage of AI techniques. Section 7 describes the validation performed, and finally Section 8 concludes the paper by presenting also relevant lessons learned and current adoption.

2. Related work

So called Health Smart Homes (HSHs) and Healthcare Monitoring Systems (HMSs), as surveyed in [1], are an integration of ubiquitous computing and communication technologies. These systems have emerged as a promising solution to provide health services that match the context and real needs of subjects. Several studies and solutions have been proposed to address diverse aspects of these systems (interestingly [1] cites over 200 different works). In general, these solutions share common goals and properties: their main objective is to provide a smart environment where the system monitors and evaluates the health conditions of subjects and provides them with timely e-health services. [1] carefully analyzes those proposals and identifies some weaknesses, main challenges and still open issues. A few approaches consider, in a systematic way, the subject's context: a lot of existing work take whatever is measurable and consider it as the subject's context, then they use modelling techniques to detect anomalies and when abnormal behaviour is detected, the subject's health status is deemed to have changed. Health and behavioural systems for the elderly have been defined based on the availability of sensing rather than the use of medical/expert/geriatric knowledge and a good understanding of the subject's context. The lack of such considerations leads to high uncertainty in the success and adoption of such projects. Sempre Vicini has addressed such a concern, by adopting a *medical-leaded* approach instead of a *technology-leaded* one: the achievement of basic activities of daily living (ADLs) and the analysis of health conditions is considered, and not ad-hoc.

[2] evaluates a rapid prototyping solution for information merging based on five health sensors and two low-cost ubiquitous computing components: Arduino and Raspberry Pi. The study, entirely aimed at reproducibility, evaluates the extent to which portable technologies are capable of integrating wearable sensors. The results are quite encouraging, showing that the technology is mature but not yet fully scalable on very large deployments, as also previosly argued by the Whole System Demonstrator Programme (WSD) [3]. A few years ago, this program was promoted by the National Health System of the United Kingdom to stimulate the adoption of telecare; the main purpose was to provide more than 6000 patients with tools to manage their chronic conditions with a tight supervision of clinical staff (up to 238 physicians) through the use of sensors for monitoring physiological signals integrated into a complex communication system.

The adoption of AI and data mining techniques to health has been recently surveyed, specifically for the European landscape, in [4]. With this respect, Assisto eCare 4.0 adopts some of the more recent techniques, in particular those ones based on neural networks, in order to predict possible anomalies of patients and trigger corrective actions (as it will be further explained in Section 6).

3. Medical background and assumptions

Generally speaking, health is not identified in the absence of disease(s), but in the feeling of *well-being* that allows a person to maintain adequate activities. The quality of life (QoL) is highly cited, but currently is poorly used in the clinic practice; several tools for QoL assessment are largely based on self-assessment and easy to compile. The QoL also serves to establish the years lived with a good quality of life (therefore also takes into account mortality) possibly thanks to a specific treatment and possibly also evaluating the costs incurred to obtain that result (cost-utility analysis).

Three elements are integrated into Evidence Based Medicine (EBM): the patient's situation, scientific evidence and the doctor's experience. EBM is also used for older people although they are excluded in controlled clinical trials (CCTs); CCTs rarely consider the specific needs of the elderly and do not even foresee endpoints such as their preferences, quality of life and self-sufficiency which are fundamental for the elderly. Aging profoundly changes the physiology of the organs making them more vulnerable and differently responsive to drugs and also to the social and psychological existential situations that gradually arise. In the elderly, the risks, complications, burden of the disease prevail and also the reduced effect of drugs and treatments.

Multipathology and polytherapy greatly complicate the clinical picture and the results of the treatments: this must be taken into account. The heterogeneity of the elderly and oldest subjects easily leads to overtreatment of frail elderly people and undertreatment of elderly people in excellent condition. There is no qualified clinical reference tool that helps the doctor who must prescribe a treatment plan for an elderly person; it is necessary to evaluate the elderly patient's physical, mental and social functions and performance to identify vulnerability and establish treatment goals.

So the EBM does not have the requirements to be transferred to the elderly population; the doctor can use it, but taking into account the biological, psychological and social characteristics of the old patients. The health organization based on the single disease is not adequate to tackle the problem of multimorbidity even at the level of training of health and social personnel of various levels. Multimorbidity is increasingly relevant with the aging of the population; it is associated with high mortality and disability and involves a greater use of health services, from the hospital to specialist clinics, also posing the problem of the quality of health and care services widely used by the elderly population.

Only 40% of the elderly have typical symptoms as expected by the traditional one-disease model. In geriatrics, a-typicalness, non-specificity of symptoms as well as undereporting of symptoms are common. A change in clinical conditions requires a multidimensional geriatric evaluation and a review of the ongoing treatments, in particular of the drugs taken. The so-called *giants of geriatrics* include falls, delirium, reduced mobility, iatrogenesis, urinary incontinence, loss of ability to perform ADL, cognitive decline.

The setting plays an important role: in the emergency rooms, atypical evidence of diseases is present in about a third of the elderly who access them and mainly concerns the episodes of fall which represents a true geriatric syndrome. The absence of fever is also frequently encountered; urinary tract infections and dementia are the atypical presentation risk factors frequently found in this setting. Diagnosis in these cases requires forethought, but also time to emerge: intensive-short-observation structures can represent a functional organizational model for geriatric patients to overcome the clinical problems mentioned. In nursing homes, 90% of the guests are frail because of the many chronic diseases and the consequent cognitive, affective and functional problems; they are vulnerable to direct and indirect damage from medicines.

The setting affects the behavior and appropriateness of the interventions. Hospitalization of the elderlies is not always the most appropriate decision; in fact, the results of hospitalization of very old persons are often not good. The hospitalized elderly person is "acute" even if he has multipathology and variable disability and a geriatric syndrome: the hospital is often unable to offer proportionate and qualified care and assistance to this case.

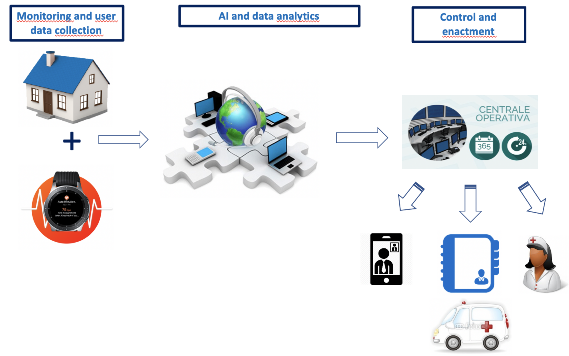

Figure 1. The Assisto eCare 4.0 architecture

4. Functionalities of the system

The main concept of Assisto eCare 4.0 is that, through home automation and biometric bracelets, a user (for example elderly or chronically ill) will be assisted 24 hours at home and away, and in case of "values" out of the norm, an intelligent system will activate a series of actions. In automatic mode (without human intervention) and in real time the system will decide, for example, if activating a video call on the smartphone with a relative, or activating a control center, sending an emergency patrol, finding exactly where the person is located, etc.

It is basically an IoT- and AI-based project applied to the sector of personal well-being, security and social assistance for the elderly. Indeed users are paying increasingly attention to a healthy lifestyle, but they need to be stimulated to do physical activity, eat properly, monitor vital parameters, etc. Assisto eCare 4.0 fully controls weight and fat mass, good and bad cholesterol, sleeping habits, etc. and is able to offer the diet to follow during the week, tailored on the basis of the the movement made and the stress endured. Assisto eCare 4.0 can verifies that the users are not too seated and remind to walk, or conversely advises to rest if they feel altered heart values. Overall, this makes the system a decision support system in which automatic methods based on AI (learning in particular) allow to suggest users (monitored persons, operators and relatives) on the most appropriate actions in case of anomalies, without a manual pre-configuration of rules (which has proven to be time-consuming and not tailored to specific needs) but on the basis of continuous analytics and prediction techniques.

In parallel with the feeling of well-being, the feeling of security derives from many factors, the first is to have the certainty of never being alone. Assisto eCare 4.0 controls users' homes and is activated in the event of gas leaks or electrical problems, breakdowns, in the event of intrusion by thieves, etc. activating actions that can range from the call of

Figure 2. The ASSISTO eCare 4.0 smartwatch

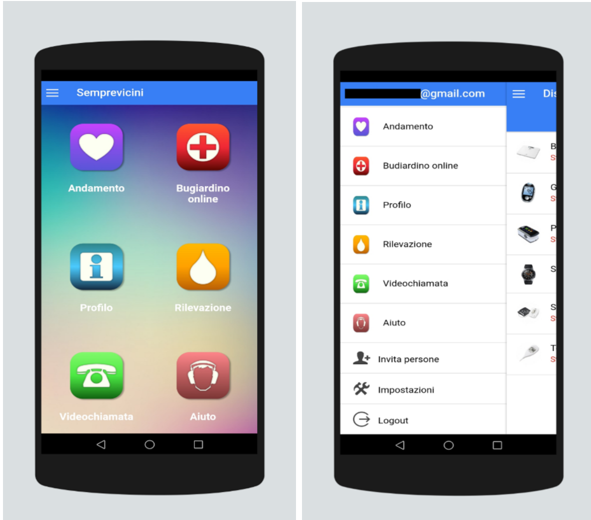

Figure 3. The ASSISTO eCare 4.0 mobile app (menu is in Italian

an operator who supports in the solution, up to the prompt intervention of armed surveillance or a social worker.

ASSISTO eCare 4.0 allows also relatives to constantly check vital parameters of monitored persons, at home, in the hospital, when they are out.

Figure 1 depicts the conceptual architecture of the platform. A domotic system is complemented by a biometric detection device for use outside the home, also necessary to detect the location of users and any fall. In the case study, Galaxy Gear SM-R805F smartwatches with a virtual SIM have been used and a aspecific app has been developed in Taizen. The functionalities of the smartwatch app are (a) heart beat detection, (b) GPS position detection, and (c) fall detection. Figure 2 shows such a device and the app.

The platform consists also of a smartphone app that enables the user to enter the parameters (using the supplied biometric devices) and to control them. Through the app, currently developed for Android (cf. Figure 3), the user can consult all the available items:

- Home: presents a summary of all the basic functions of the application
- Trend: allows to view all personal information detected through the biometric kit
- Online leaflet: allows to search for a drug through the search engine
- Profile: an overview of the data associated with the patient
- Detection: lists the devices of the biometric kit and the communication between the smartphone and the biometric kit
- Video call: detects doctors and family members associated with the patient
- Help: lists the support number of the control center and for convenience also the contacts of doctors and family members.
- Invite people: allows you to share your information with users outside the system
- Settings
- Logout

As far as the control center, which manages alarms and medical personnel for interventions, it offers a service 24x7 to all users. The main functionalities are:

- operators can interact with the platform and intervene through dedicated calls to users needing assistance;
- registry for each user, which in addition to contact data (name, surname, contact's telephone number, structure number and address), contains a clinical history from the registration of all the alerts taken;
- alarm reception and management.

The service is supposed to be carried out by previously trained operators, who activates in the event of an alert all the necessary procedures relating to the specific alarm received. From the user point of view, the operator has an interface with multiple sections:

- Monitoring. The operator can locate a patient and monitor the alarms that are triggered, so that she can intervene promptly.
- Geolocalization. The operator can search the user either manually in the map or by entering the name of the latter in the appropriate search filter. Once the patient is located, the operator will be able to view the information (address, people and doctors of reference and monitored parameters) and perform a live monitoring related to the patient herself.

Figure 4. Some screenshots of the application of the Assisto eCare 4.0 control room (interface is in Italian).

- Alarms. The operator monitors the active alarms and those already taken in charge. The active alarms are divided into three codes (red, yellow and green) according to their severity and for each alarm that is triggered it is possible to view the anomalous parameter(s) with the detected value, the color code and the time of when it was detected.

Figure 4 presents some screenshots of the interface for the operators of the control room. Similar views are available for relatives of the monitored persons, via a Web app.

One main novelty of the system is in the fact that *allarms are not triggered on the basis of pre-defined and static rules (as in many of the system considered in Section 2) but on the basis of a learning process, which allows the tailoring on the specific user* (as further discussed in Section 6).

5. Architecture and design of the proposed system

From the software architecture point-of-view, Figure 5 depicts the architecture of the platform.

The application storage is based on a Microsoft SQL Server 2016 engine, accessible from the Microsoft .NET platform through the features exposed by ADO.NET. The

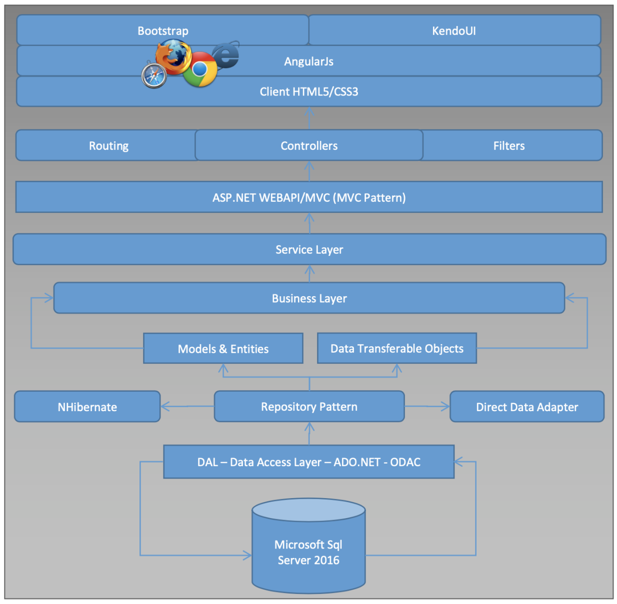

Figure 5. The software architecture

Data Access Layer is then integrated through a Repository Pattern that transparently exploits access to the data through the OR/M NHibernate or direct access to the Data Reader (for operations that require a run time particularly high).

The production of entities, models and DTOs (Data Transferable Objects) operated by the repositories themselves, allow to manipulate the relational model using a business-oriented approach. The CRUD operations (Create, Update, Read and Delete) are carried out completely on persistence models, thus allowing the application of data validation logics, and maintaining a consistency of the entities managed. The two layers placed above (Business Layer and Service Layer) are those that contain the entire functional flow of the system, and expose the "public" functionalities of the same through a series of services invocable from the user interface, or from the Web services with which the module itself is equipped. The exposure of the services is guaranteed through HTTPS protocol in JSON format.

On top of this "core" of the system, the GUI (Graphic User Interface) and communication services with the external ecosystem are built. Since the central module is operational in a Web environment, it is used through a browser supporting the HTML5 and CSS3 specifications (Google Chrome, Mozilla Firefox, Internet Explorer 9+, Safari).

The combination of a backend server based on the ASP.NET Web API engine, ASP.NET MVC and serializations in JSON format, combined with the client exploitation of Javascript frameworks such as AngularJs, is the right answer to the problem of addressing adequately both the bandwidth problem and the latency problem, in addition to clearly promoting the increase in user experience and productivity in using the platform. System authentication is managed through OAuth 2.0. This last choice has allowed us to provide specific authorization flows for web, desktop and mobile applications, ensuring high standards of scalability, modularity and security. Overall, the client-side technologies which have been adopted are AngularJs, KendoUI, BootstrapUI, CSS3, HTML5, JQuery and BootstrapJS, whereas on the server-side we adopted ASP .NET Web API, ASP .NET MVC, NHibernate, ADO.NET, Automapper, Owin and Log4Net.

The software has been developed in 6 months, through an agile Scrum-based approach, with duration of the single sprints of 2 weeks. *Design thinking* methods have been applied all over the project, and notably security (also due to the type of data managed by the system) has been considered as crucial, in particular the system can be defined as *GDPR by-design*.

6. AI - Learning module

One of the goals of the project has been the design of an AI module able to improve medical diagnosis by analyzing, searching, and classifying patterns in the observed measurements.

The idea was to apply state of the art machine learning techniques, following a supervised approach, in order to get insights from the temporal trends of the observed measurements. To do that, the first step was related to the design of a labeled dataset that is composed of comorbidities associated to several time windows of measurements for each patient.

Each comorbidity reflects the risk, for a patient, associated to a specific illness. In particular, 14 possible diseases have been considered during the project, each one marked with 5 possible risk levels (0: no risk; 4: high risk). The problem can be considered a classification one where the input features are given by the set of measurements and the output is the risk level associated to any possible disease.

In order to analyze the temporal trends of the measurements related to each patient, a Recurrent Neural Network (RNN) has been designed. In particular, we designed a Long Short Term Memory (LSTM): a particular RNN which uses an efficient gradient based algorithm to keep constant the error avoiding its explosion or vanishment [5]. The main advantage of LSTMs with respect to traditional RNNs is given by the fact that they are able to keep in memory time dependencies between inputs for a longer period.

Fig. 6 shows an LSTM cell, that internally is composed of three gates (input, output, forget) according to the following equations.

$$f_t = \sigma(W_f * [h_{t-1}, x_t] + b_f) \quad (1)$$

$$i_t = \sigma(W_i * [h_{t-1}, x_t] + b_i) \quad (2)$$

$$\widetilde{C_t} = tanh(W_C * [h_{t-1}, x_t] + b_C) \quad (3)$$

$$C_t = f_t \circ C_{t-1} + i_t \circ \widetilde{C_t} \quad (4)$$

$$o_t = \sigma(W_o * [h_{t-1}, x_t] + b_o) \quad (5)$$

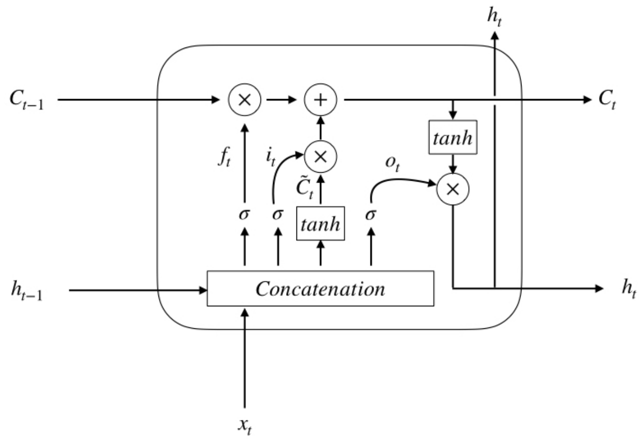

Figure 6. LSTM cell.

$$h_t = o_t \circ tanh(C_t) \quad (6)$$

where ∘ is the element wise product, f_t,i_t,o_t are the *forget gate*, the *input gate*, and the *output gate*, and W_f, W_i, W_C, W_o are the weight matrices of the forget gate, input gate, cell state, and output gate.

The first step consists in deciding what information is necessary to keep and what is not. This decision is made through eq. (1) which takes as input the data array x_t at the time instant *t* together with the output h_{t-1} coming from the time instant *t-1*. In such a context, x_t is an array containing for each time instant *t* a collection of data representing the input features of the system (e.g., comorbidity data). The result obtained is then passed as input to the sigmoid activation function σ which returns a number between 0 and 1 for each element of the cell state C_{t-1} where 0 means that the element can be forgotten while 1 means that the element has to be kept over time. The second step involves the input gate and allows the LSTM to establish which of the new information to store. This is done by executing two sub steps, the first one consists in passing the new information to a sigmoid activation function (eq. (2)) which returns a value between 0 and 1 just like the previous step, where 1 means that the element has to be updated while 0 means that the element has not to be updated. The second substep allows to compute the new state values through eq. (3) where the hyperbolic tangent *tanh* is an activation function adopted mainly for two reasons: *i)* it normalizes the output between -1 and 1; *ii)* it has a derivative which is particularly fitting to address the vanishing gradient problem which affects traditional RNNs. At the end of these substeps, the new LSTM cell state can be updated through eq. (4) which will be a combination of the new values computed in the current timestep (eq. 3), and the values coming from the previous one. Finally the last step allows the generation of the LSTM output through eqs. (5) and (6) that select which part of the new LSTM state to output.

In order to design an LSTM suitable for our classification problem, we followed a deep approach by designing

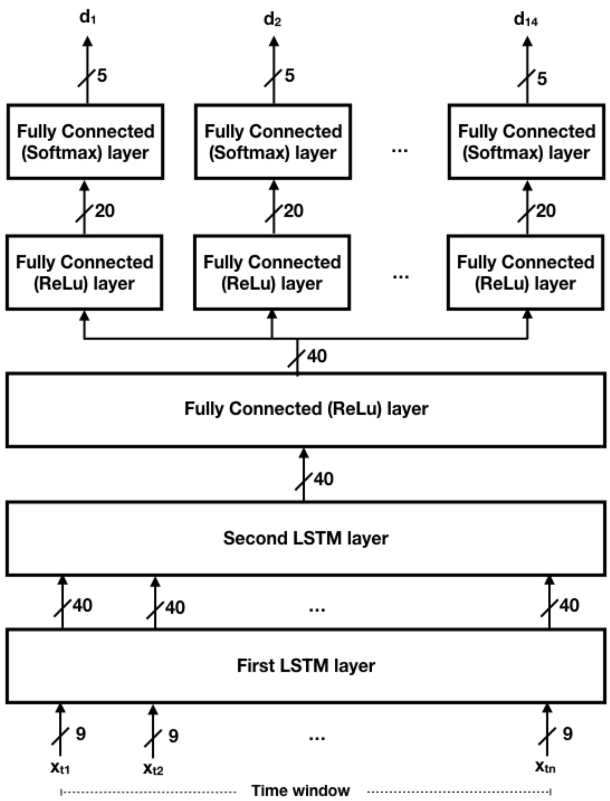

Figure 7. Model architecture.

an architecture composed of different LSTM layers and inserting some final dense layers that take care of returning the correct output. Fig. 7 shows the proposed architecture. The first LSTM layer takes into account a time window of data, in particular each data point is characterized by 9 measurements corresponding to different patient parameters. The dimension of the time window is considered a hyperparameter that can be set in a following tuning phase. The second LSTM layer takes as input the features extracted by the first layer (still in a time window fashion) and returns a new set of high level features. Such features are then passed to 14 (one per disease) fully connected layers (with ReLu activation function) that following a 40-20-5 schema give in output the corresponding classification thanks to a final softmax activation function.

For the LSTM implementation we used Keras [6], a high level API written in Python that runs on top of very powerful machine learning frameworks like Tensorflow, Theano, and Caffe [7],[8],[9].

7. Case study

The case study has been conducted on frailty elderly defined as autonomous or partially non-autonomous guests of the "La Pace di Viterbo" nursing home, who have been subjected to monitoring of parameters detected using biometric technologies, plus a sample of persons living at their houses recruited in the Ronciglione area.

Guests of both sexes meeting the following criteria were included in the study: age > 60 years, score at the Mini Mental State Examination (MMSE) > 23; and the following exclusion criteria: liver and kidney diseases such as to impair cognitive status during the duration of the study; treatment with drugs for which an effect on mood and memory is known. All guests underwent physical examination and blood chemistry at the beginning and end of the study.

The study required written and acknowledged informed consent containing the description of the processing of personal data in relation to the testing by all participants.

The following parameters have been be monitored via wearable sensors:

- heart rate;
- blood pressure;
- oxygen saturation;
- glucose;
- body weight;
- body temperature;

- motion (via a motion sensor);

The study has been completed by the following parameters:

- Parameters related to the demographic characteristics of the population: age, sex, incomes, residence, schooling, ethnicity, marital status, living environment, and lifestyle (healthy behavior: smoking, alcohol consumption, physical activity, changes in body weight, eating habits, sleeping);

- Physical frailty parameters: mobility, measured through Short Physical Performance Battery (SPPB), balance test, gait speed (3 or 4 meters), circumference of the calf and arm, muscle strength (hand grip test, hand grip strength); Cumulative Illness Rating Scale – CIRS; comorbidities (Charlson Comorbidity Index – CCI); pain (Visual Analogical Scale – VAS);

- Mental fragility parameters: diagnosed dementia or cognitive impairment (Mini Mental State Examination – MMSE), depression (Geriatric Depression Scale – GDS), Euro Quality of Life Questionnaire;

- Nutritional fragility parameters: appetite, body weigth, body mass index, mininutrional assessment (MNA);

- Service satisfaction questionnaires

- Daily life activity score (ADL) (Barthel index) and Instrumental activity of daily living score (IADL).

The study had a maximum duration of 7 months. The first phase lasting 1 month, provided for the selection of the elderly participants while the second phase, lasting a maximum of 5 months, provided for the provision of the service; finally, the third phase (month 7), corresponds to data processing.

The results include the evaluation of 22 elderly people, 5 living at their own home and 17 guests of the retirement home. Table 1 lists the participants (average age 86.09 years; 15 females, 7 males) and the alarms triggered during the observation period for a total of 434.

The yellow alarms triggered (total 296), in the majority of cases, corresponded to values lower than the normal body temperature. They were simultaneously verified and found to be non-pathological and therefore considered to fall within the normal range for their guests. The red triggered alarms (total 80) corresponded to low maximum blood pressure values compared to the normal ones. The value of such results is not in their precision and recall (which are indeed not optimal) but in the learning that they allowed on the system, which has been really trained during operations (and not with synthetic data as in the most of cases). None of the alarms resulted in the hospitalization of the corresponding guests; they have been notified, verified and evaluated by their general practitioners. Overall, there have not been false negative, which is the most critical performance indicator for such a type of system (whereas a false positive implies an healthy patient which is given attention - not needed, a false negative implies patient needing assistance which is not considered due to the absence of an allarm, and may result in damages to the patient herself). The operations center was considered efficient, it allowed the employees to intervene instantly and effectively, guaranteeing users assistance and safety.

Although the case study does not allow statistical analysis of the data, it is important to provide a detail of the CIRS and EuroQuality of Life scores (see Table 2).

The severity index and comorbidity index averages show us respectively the presence of mild / moderate impairment in at least 2 categories and a score greater than or equal to 3 in at least 3 categories.

As for the EuroQuality of Life, the study participants expressed that they had a sufficiently good health level with an average value of 65.45 (scale 0–100); value confirmed by the estimated health score of 0.539 on average (scale 0–1).

Finally, during the last month of the case study, a final evaluation questionnaire about the overall service was submitted. Here is the full text (in English, the original one was in Italian).

> The SEMPRE VICINI project is coming to the end. We therefore ask you to express an evaluation on this experimental project. Express a numerical preference from 1 to 4, where 1 corresponds to a minimum score (disappointing), 2 to a sufficient score, 3 to a good score and 4 to a maximum (excellent) score.
>
> 1. How do you rate your general experience on the project?
> 2. Do you feel more relaxed compared to the beginning of the experiment, with the monitoring and use of these technologies for well-being and safety? Do you live better?
> 3. Your relatives, sons, etc. do they feel more comfortable knowing that you are a monitored user 24x7?
> 4. How do you rate the technical staff and assistants who supported you in this pilot project?
> 5. With regard to the technologies used, both for the part of the devices and for the part of the IT applications, what do you think?
> 6. Can you give us some opinion on how to improve the service? Report the answers in the open field.
> 7. If it were a paid service, would you recommend it to a friend?

Table 1. List of the participants and raised allarms.

Participant	Where	Sex	Birth year	Age (years)	Total raised allarms	Green raised allarms	Yellow raised allarms	Red raised allarms
1-FP	Residence	F	1929	90	29	0	15	14
2-AC	Residence	F	1938	81	10	4	2	4
3-GB	Residence	M	1932	87	6	0	4	2
4-UDO	Residence	M	1934	85	35	0	23	12
5-GM	Residence	M	1945	74	62	0	60	2
6-LM	At home	F	1936	83	43	2	37	4
7-BDG	At home	M	1934	85	9	3	4	2
8-AnC	Residence	F	1930	89	6	0	2	4
9-MP	Residence	F	1930	89	43	27	13	3
10-RB	Residence	F	1932	87	54	0	50	4
11-SI	Residence	M	1946	73	21	0	19	2
12-AG	At home	F	1944	75	15	1	14	0
13-GM	Residence	F	1925	94	20	0	3	17
14-ER	At home	M	1942	77	10	2	2	6
15-AL	At home	F	1929	90	37	1	36	0
16-AFM	At home	F	1934	85	27	14	11	2
17-MP	Residence	F	1924	95	0	0	0	0
18-CP	Residence	F	1919	100	0	0	0	0
19-EB	Residence	F	1936	83	0	0	0	0
20-MPS	Residence	F	1926	93	0	0	0	0
21-AR	Residence	F	1936	83	4	4	0	0
22-VDS	Residence	M	1923	96	3	0	1	2

”

The results derived from the final evaluation questionnaire of the service show that the majority of participants rated the service as excellent (cf. Table 3):

- Question 1: 77.27% excellent score and 22.73% good score;
- Question 2: 81.82% excellent score; 18.18% good score;
- Questions 3 and 4: 100% excellent score.

Furthermore, the answers to questions 5, 6 and 7 (see the Appendix) indicated that the elderly population involved in the study, with an average age of over 80 years, overcame the initial doubts and appreciated the service, technologies included, in terms of safety and advantage for their own health, so much that it is also recommended for a fee.

Overall, we can argue that the objectives of the pilot study were caleachieved in terms of hours provided and the validity of the use of sensors which, by detecting vital parameters, represent a way to assist a frail elderly person and to mediate/share with the caregivers/socio-health workers/doctors/social workers. Notably, the learning phase of the system has been successfully perfomed avoiding false negative cases.

8. Lessons learned and concluding remarks

It is of the utmost importance to continue working with social and socio-health objectives by reducing the gap between technology, frail elderly people, social and socio-health workers and assistants to improve the quality of health and life. Preventing or minimizing the transition from damage to disability to handicap (according to the old principle than "better safe than sorry") implies empowerment and a more active role in health management in order not to medicalize other aspects of everyday life. Social health is a concept for which acute medical problems are not identified and the reasons that trigger the presentation could be the loss of support or the increase in care needs. It is a very broad concept of health, comparable to the welfare community, or the prospect of developing health promotion models closely connected with local actions and

Table 2. Indexes. Severity index: average of the scores of the first categories (excluding the category psychiatric / behavioral pathologies); comorbidity index: number of categories in which a score greater than or equal to 3 is obtained (excluding the category psychiatric / behavioral pathologies).

Participants	CIRS§		EURO QUALITY OFLIFE*	
	Severity	Comorbidity	Health level (0-100)	Health value (estimated points)
1-FP	2,08	5	70	0,516
2-AC	1,62	4	60	0,585
3-GB	2,08	6	70	0,743
4-UDO	2,08	5	60	0,587
5-GM	1,54	2	70	0,779
6-LM	1,69	3	80	0,743
7-BDG	2,15	5	60	0,516
8-AnC	1,85	5	70	0,656
9-MP	2	5	50	0,656
10-RB	1,62	4	50	0,639
11-SI	2,08	5	70	0,743
12-AG	1,77	4	70	0,516
13-GM	1,69	3	50	0,585
14-ER	1,31	1	90	0,796
15-AL	1,54	2	70	0,62
16-AFM	1,77	4	80	0,587
17-MP	2,23	5	60	0,725
18-CP	1,85	3	100	0,639
19-EB	1,92	4	40	-0,323
20-MPS	2	5	50	0,024
21-AR	1,92	3	70	0,516
22-VDS	2	4	50	0,024
Average	***1,85***	***3,952380952***	***65,45454545***	***0,539636364***

services to be carried out in the local community mainly through the creation of territorial services with high social involvement and the exercise active citizenship aiming at the effective improvement of the quality of life. Socio-economically vulnerable patients are more likely to be referred to a residential care facility, in the absence of services designed to protect social health. We must keep in mind the case histories of the elderly who access the hospital emergency room for social reasons, for the impossibility of staying at home alone for not only medical reasons, such as the inability to take care of themselves and to have a family / caregiver constantly present. Today we tend to deal almost exclusively with the negative aspects of health and especially when clinically relevant and evident problems emerge (waiting medicine): this happens especially in geriatrics.

Sempre Vicini is social innovation both in content and in the organizational model. It aimed at carrying out an innovative project of social assistance, well-being and safety of the weaker population by using a technological architecture equipped with artificial intelligence and with biometric technologies. It is evident that the results and the benefits for the community are enormous and the fallout and spill over are so great that they are difficult to measure. Despite this premise, an effort has been made to quantify them and therefore make them measurable and accountable. In this paper we have described the main components and the case study, with 22 seniors supported for 5 months, and over 80 000 hours of monitoring on the elderly users involved.

As described in this paper, the system is an Internet-of-Things and Artificial Intelligence with biometric technologies project applied to the social care sector for the elderly. The release of the IT architecture has been performed according to "open" licenses (the system is released with the European Union Public Licence – EUPL), and its functionalities are offered according to the API-as-a-Service model; this means proposing itself with a pioneering model of social open innovation, which is to develop and test the IT system and then to make it available to all those who want to use it. In fact, with open standard, open framework, open data, open source licenses, we guarantee that the system can be reused by everyone. Currently (July 2021) the system has been engineered and offered by a consortium of different industries, including Assisto and Live Protection (Linkem), and is operative in the Rome area

Table 3. Satisfaction results.

Participant	Question 1	Question 2	Question 3	Question 4
1-FP	4	4	4	4
2-AC	4	4	4	4
3-GB	4	4	4	4
4-UDO	4	4	4	4
h5-GM	4	4	4	4
6-LM	4	4	4	4
7-BDG	4	4	4	4
8-AnC	4	4	4	4
9-MP	3	4	4	4
10-RB	4	4	4	4
11-SI	3	3	4	4
12-AG	4	4	4	4
13-GM	3	3	4	4
14-ER	4	4	4	4
15-AL	4	4	4	4
16-AFM	4	4	4	4
17-MP	3	3	4	4
18-CP	4	4	4	4
19-EB	4	4	4	4
20-MPS	3	3	4	4
21-AR	4	4	4	4
22-VDS	4	4	4	4

(cf. https://roma.repubblica.it/cronaca/2021/04/18/news/roma_assistenza_high_tech_a_domicio_trenta_tablet_agli_anziani_del_municipio_i-297014020/).

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Appendix

The appendix reports the answers (free text) given to some questions of the satisfaction questionnaire (translated in English, original ones were in Italian)

QUESTION 5 - With regard to the technologies used, both for the part of the devices and for the part of the IT applications, what do you think?

1 - I don't know how to use them but they seem useful to me
2 - Needed
3 - I don't know
4 - They facilitate the health check
5 - I like them but I don't know how to use them
6 - Excellent
7 - I didn't know them but they seem useful to me
8 - I found myself well
9 - I thought worse at the beginning then I understood
10 - I doubted a little but I felt immediately at ease
11 - I found myself quite well even if I don't like them
12 - They are modern and better than the old ones
13 - I don't know what to say
14 - I will not learn to use them but I understand that they are good
15 - I am amazed
16 - I noticed that they are simple to use
17 - I can't evaluate
18 - I found everything well but I was worried about breaking them
19 - These tools are difficult but I'm sure better than those of the past
20 - I don't know
21 - Incredibly better in comparison to my times
22 - I tried to understand and they are simpler than I could imagine

QUESTION 6 - Can you give us some opinion on how to improve the service?

1 - Excellent as well
2 - The operators were perfect
3 - All as good as you did
4 - For me, the important thing is that someone follows the measures
5 - For me already so much and well
6 - Everything as good as now
7 - I hope to continue like this
8 - I don't feel like adding anything to improve it
9 - Next time I would like to know if I can choose the times
10 - Everything was well organized I didn't have any discomfort
11 - I can't complain so it's fine
12 - I'd add some more checks
13 - The service was good
14 - I don't know what to say
15 - I can say that I would accept any other modernity, I have become familiar with these gadgets
16 - The service is already too good, sometimes I wished it was interrupted for a while
17 - For me it's fine so I don't know
18 - I can't say I always felt well assisted
19 - For me it can continue like this
20 - Okay so
21 - I wouldn't add anything else for the moment
22 - I wish we could receive more training

QUESTION 7 - If Sempre Vicini were a paid service, would you recommend it to a friend?

1 - yes
2 - yes
3 - yes
4 - yes
5 - yes
6 - yes
7 - yes
8 - yes
9 - yes
10 - yes, do you know the cost?
11 - yes
12 - yes, regardless of the cost I imagine within the possibilities of us elders.
13 - yes
14 - yes
15 - yes
16 - yes
17 - yes
18 - yes
19 - yes
20 - yes
21 - yes
22 - yes, in the hope that it will be affordable by everyone