Acronym: vINCI
Name: Clinically-validated INtegrated Support for Assistive Care and Lifestyle Improvement: the Human Link
Call: AAL 2017 “AAL Packages / Integrated Solutions”
Contract no: AAL2017-63-vINCI
Start date: 01 June 2018
Duration: 36 months

D2.2 Report on technical specifications of the developed kits

Nature[1]: R
Dissemination level[2]: CO
Due date: M24 (May 2020)
Partners involved (leader in bold): ICI, **MPU**, UNRF, NIT, CMD, AUT, SAL, NIGG, CTR

Project Co-Funded by:

Project Partners:

---

[1] L = legal agreement, O = other, P = plan, PR = prototype, R = report, U = user scenario

[2] PU = Public, PP = Restricted to other programme participants (including the Commission Services), RE = Restricted to a group specified by the consortium (including the Commission Services), CO = Confidential, only for members of the consortium (including the Commission Services)

Partner list:

No.	Partner name	Short name	Org. type	Country
1	National Institute for Research and Development in Informatics	ICI	R&D	Romania
2	Marche Polytechnic University	MPU	R&D	Italy
3	University of Nicosia Research Foundation	UNRF	R&D	Cyprus
4	National Institute of Telecommunications	NIT	R&D	Poland
5	Connected Medical Devices	CMD	SME	Romania
6	Automa Srl	AUT	SME	Italy
7	Optima Molliter (f. Salvatelli) Srl	SAL	SME	Italy
8	National Institute of Gerontology and Geriatrics "Ana Aslan"	NIGG	R&D	Romania
9	Comtrade Digital Services	CTR	Large enterprise	Slovenia

Revision history:

Rev	Date	Partner	Description	Name
1	19.12.2019	MPU	Created the template, drafted sections and content	Susanna Spinsante
2	19.12.2019	SAL	Added content	Susanna Salvatelli
3	19.12.2019	AUT	Added content	Matteo Pucci
4	20.12.2019	ICI	Added sections and content	Ciprian Dobre
5	20.12.2019	CMD	Added sections and content	George Georgescu
6	03.01.2020	MPU	Added sections and content	Susanna Spinsante

Contents

1 Introduction **2**

1.1 Scope of this document . . . 2

1.2 Data Collection in the vINCI Platform . . . 2

1.3 A Sample Scenario . . . 3

1.4 vINCI Sensing Technologies and Components . . . 4

1.4.1 Smart Insole . . . 4

1.4.2 Smartwatch . . . 13

1.4.3 Depth Cameras-Based Sensing . . . 13

1.4.4 First Operational Protocol to Run the Pilots . . . 17

2 Room Kit (TBC) **19**

2.1 Aimed Service and Requirements . . . 19

2.2 Room Kit Components . . . 19

2.3 Room Kit Integration . . . 20

3 Activity Kit (TBC) **21**

3.1 Aimed Service and Requirements . . . 21

3.2 Activity Kit Components . . . 21

3.3 Activity Kit Integration . . . 21

4 Biomarkers Kit (TBC) **23**

4.1 Aimed Service and Requirements . . . 23

4.2 Biomarkers Kit Components . . . 23

4.3 Biomarkers Kit Integration . . . 23

5 Social Kit **24**

5.1 Aimed Service and Requirements . . . 24

5.2 Social Kit Components . . . 24

5.3 Social Kit Integration . . . 24

List of figures **26**

Chapter 1

Introduction

1.1 Scope of this document

The four vINCI monitoring kits (Room – Activity – Biomarkers – Social Kit) foreseen by the project are developed based on the integration of the sensing devices provided by the partners, both the existing ones and those that are being designed or arranged on purpose for the aims of the project. This deliverable describes the sensing components and also the integration of such technologies, attained through the development of the necessary interfaces, APIs (Application Programming Interfaces), or software components possibly missing. Each kit is focused on a specific monitoring service, for which integration is carried out in a lab environment, in close interaction with the platform development activities, details of which are going to be presented in Deliverable D2.4.

1.2 Data Collection in the vINCI Platform

The data collecting platform will be deployed on servers available at NIT's PL-LAB facility. The platform will by accessible on a public IP address. The platform will provide a set of interfaces (associated with distinct ports) adapted to different data inputs. Received data will be recorded and provided to the analysis module in unified format.

The vINCI data collection platform allows gathering data from different inputs (data sources):

- Smartwatches – the data produced by smartwatches will be obtained via an API available at the CMD platform (an appropriate interface will be implemented in the collecting module);
- Smart insoles – the data produced by them will be obtained first through a gateway represented by a smartphone with an internet connection. The smartphone will gather data from the insole locally, over a Bluetooth Low energy link, and relay the data to the platform by exploiting a WiFi connection. In a second development, in order to allow the use of the insole even without the local support of a smartphone, a LoRA interface will be possibly provided in order to enable data transfer through a LoRa Gateway, from the insole to the platform, over a long range link;
- Depth cameras – the data produced by them will be sent to the collecting module using wired connection;
- Clinical questionnaire filled in by the patient – an application developed for a tablet used by the patient and the operators will send data to the collecting module using WiFi or LTE connection;
- Medical investigations – data provided by the clinical personnel will be sent to the collecting module using wired or wireless connection (Ethernet/WiFi/LTE).

The different data sources feeding the platform, and the related data flows, are schematically depicted in Figure 1.1.

In the case of the analysis module, it can be also deployed on the PL-LAB server (e.g. as a separate virtual machine), or it can connect with the data collecting module remotely, via Internet. Analysis results will be available to the older adult and/or the caregiver via an interface provided by the analysis module. Another option is that the analysis module will return results of performed computations to the collecting module, and the collecting module will record the results in its repository and next make them available to the older adult and/or the caregiver.

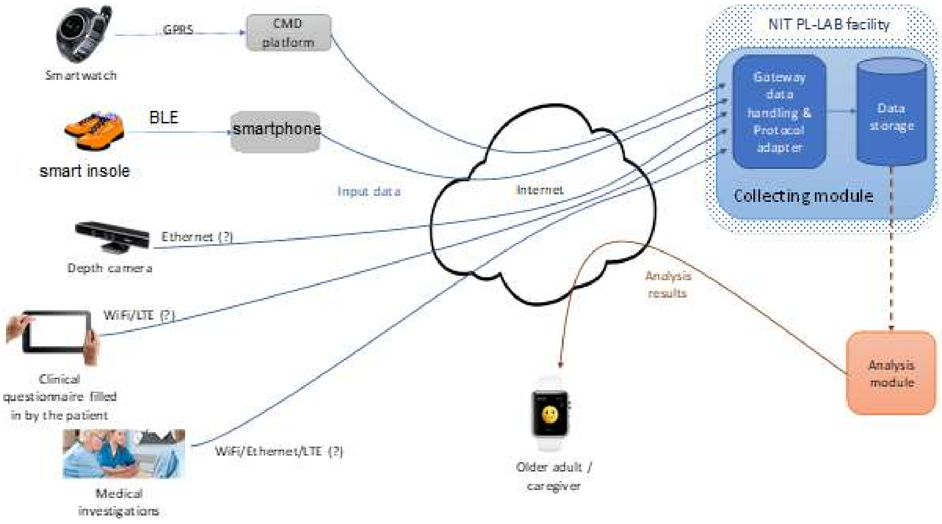


Figure 1.1: vINCI collecting platform scheme and data flow diagram.

vINCI will develop an IoT (Internet of Things)-based ecosystem to deliver non-intrusive monitoring and care support for older adults. Personal sensed data will be securely monitored starting from sensors (e.g. detecting physical and social activity), coupled with data gathered from wearable devices (e.g. smart watch, smart shoes/insoles). To form a true informative ecosystem (the vINCI network), IoT endpoints will support standards-driven communication protocols combined with sophisticated data aggregation and analytics techniques. Adequate models will be developed to assess the older adult's QoL (Quality of Life) profile, identify impairments associated with old age, and help aging people getting a sense of independence. Traditional medical services will be augmented with monitoring capabilities, such that the caregiver will have access and track exercises, activities, health status, being able to adapt the caregiving procedures against variables designed to lead to an increase in the level of wellbeing, QoL and perceived health.

1.3 A Sample Scenario

vINCI proposes ICT-based means to support QoL, wellbeing and health, for older adults, and to cost-optimize care processes. As a user, you would be wearing a completely trendy and non-intrusive watch, the THL™One. THL™PLUS has also sensors for EKG, Heart Rate, Step Counter, Fall Down detection. Or, you will be monitored by depth-sensors for indoor situations. On the processing side, each user is described by a profile or a model (extension to existing technology). Before enrolling into vINCI professional caregiving, you are first interviewed by your professional caregiver, with a series of questions, to construct your QoL profile, and establish a clear medical ground for delivering the most appropriate vINCI support (appropriate IoT kits for the prescribed QoL intervention). Next in time, as you start using vINCI on a regular basis, your data from the sensing devices is put to use, such that vINCI automatically learns your personal preferences (e.g. daily walking routine). This personalized model will be further used to discriminate a normal from a stressful activity. If EKG is monitored, when you are feeling lost, your heart rate gets off the charts, and so, by comparison, an alarm will be raised. When you are deviating from your typical daily walking routine, another alarm is raised. Such alarms are received by your caregiver, who will take the most suitable action: either phone you to see what happened, or in safety-related cases even send an alarm to the closest rescuing/response units. And, in all this time, even if remotely, your caregiver will be able to know through a dedicated dashboard your current position and wellbeing. The same model will be delivered as an objective evidence of whether a QoL intervention produces the desired QoL improvement, or it has to be adjusted.

Table 1.1: The IoT Kits to be integrated in vINCI

vINCI monitoring kit	Type of monitoring	Example devices	Data Artefacts
Room	Leisure, Mobility	Smart TV, Kinect	Depth sensor
Activity	Activity	THL™One, Smart shoes, RFID/BLE sensor, WiFi tracking	Location data, Exercise profiles, Fall detection
Biomarkers	Biomarkers	THL™PLUS, Fitbit Flex Samsung Gear	Heart rate blood pressure ECG Body temperature
Social	Social behaviour	WiFi/BLE sensor Kinect Facebook/Tapestry	Virtual Social Graph Edges Volunteering and external interaction Older Adult Co-Location

For these example scenarios, vINCI puts the users entirely in control of their health data. The user is able to specify what alarms can be seen by whom, what data is to be sent to whom. For example, as a user you might feel more secure if you do not show your location to everyone in the family, but prefer to share it only with your caregiver. You might even specify that alarms should be triggered only to a professional medical caregiver (you might not want to alert your family of potential threats). The vINCI network ensures that all the data is secured, such that outside the caregiver nobody will be able to track your whereabouts. And, finally, as a user you will not be bothered with a lot of annoying interface-related messages – the data is collected automatically, and alerts are triggered for your caregiver.

1.4 vINCI Sensing Technologies and Components

vINCI shall build upon TRL3 technologies being provided by the partners in the consortium or developed/re-arranged ad hoc for the aims of the project. Table 1.1 summarizes the sensing technologies and how they are combined in order to define the so-called vINCI kits, that are going to be further presented in the following Chapters of this document.

1.4.1 Smart Insole

From a Smart Shoe to a Smart Insole

The original plan of activities of the vINCI project was built on the idea of providing the users with smart shoes, i.e. shoes specifically designed for older adults by Optima Molliter Srl, and additionally equipped with electronic components, in order to be able to capture data about the user's mobility, in daily situations in the wild. One of the most succesfull products sold by the Italian company is the so-called YDA footwear, shown in Figure 1.2, which features a number of innovative elements that are specifically helpful to support active and healthy lifestyle of older adults, such as:

- The YDA heel support has a padded and comfortable internal structure, protects the heel from injury and stabilizes it during performances, embracing it gently;
- The YDA sole has been designed with an innovative Rocker design for motion control. Biomechanical control takes place at each step through Spring System technology. The ROCKER-YDA sole is made of E.V.A. ultra light and shock-absorbing with non-slip stabilizing rubber inserts. Each step is a pleasant sensory performance;
- The so-called SPRING SYSTEM is an internal insert in propulsive synthetic fiber that induces a mechanical rolling of each step. SPRING SYSTEM decreases the pressures and increases the per-

Figure 1.2: Optima Molliter's YDA footwear.

formances, stimulates the proprioceptive activity inducing the elongation of the stride, reactivates the muscles of the middle gluteus and the activity of the microcirculation;

- Easy-lace: YDA is equipped with a semi-elastic lacing system and quick slider closure. This allows a continuous adaptation to the foot ensuring maximum comfort during daily activities;
- The upper is padded, comfortable, without seams, it welcomes the foot in a protective and shock-absorbing casing;
- Soft plantar: the removable YDA footbed reduces pressure and landing shocks, it ensures foot and leg cool-down by improving performances;
- The Biogelly System is a technology inserted by injecting a revolutionary shock absorbing material into the back of the YDA midsoles. Biogelly absorbs the vertical forces exerted on the heel during each step, redistributing them on the Spring system. The result is a decrease in fatigue and an extraordinary feeling of well-being.

However, once the project started, following initial discussions with experts from Ana Aslan Institute, it was requested by them to have the possibility to test a smart ***insole***, instead of a smart shoe, for older adults, i.e. a removable part of the shoe, equipped with smart sensing technology, that could be inserted into existing shoes of the older adults, which they were already used to wear. In order to accommodate such a request from the vINCI partners, it was decided to address the design of a smart insole that could be then also re-used to engineer a smart shoe, as originally planned by the companies participating to the project. The decision to have a in-house design of the smart insole was also motivated by the fact that, performing a deep and carefull analysis of the devices available on the market, a few potential candidates were found, which were however not suitable for the project. As a matter of fact, devices such as Digitsole smart insole are designed for runners and people interested in monitoring their performances during physical activities, and require a calibration procedure with the user running on a treadmill, at different paces, for specific amount of time. This would not be possible for the older adults targeted by Ana Aslan's team.

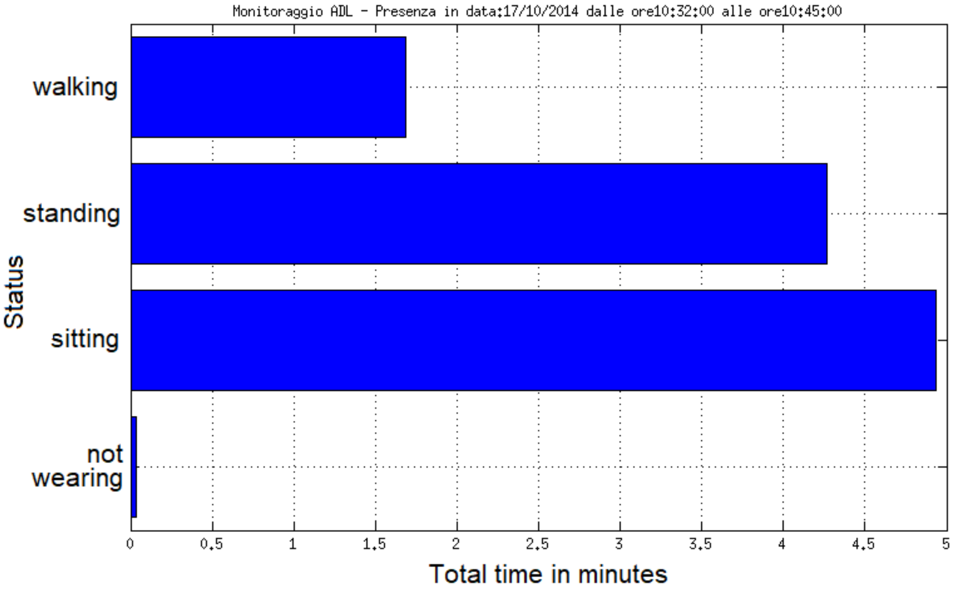


Figure 1.3: Possible representation of a user's motion statuses overview.

Smart Insole First Prototype

The first prototype of the smart insole was implemented by resorting to an existing commercial embedded platform, with the aim of testing, first of all, the feasibility of the expected sensing capabilities. In order to have a wearable, minimally intrusive device, able to somehow *measure* the activity levels of an older adult, the target metrics to obtain were set as:

- number of steps performed during an observed amount of time;
- mobility *status* associated to three different conditions, i.e. standing, walking, not wearing the insole, monitored within a specified time interval (every 3 seconds), in order to provide a more detailed report about the motion activity of the user overall the observed time.

The smart insole is designed as a sensing device equipped with a force sensor (Force Sensing Resistor - FSR) and embedded electronics. The force sensor is used to detect, by means of a proper software application running on the embedded board, the three different activity statuses detailed above. This means that raw sensor data are NOT transmitted; the information about the status is generated onboard, by processing locally the raw sensor data. Transmissions from the insole take place only at a status change, and whenever the step counter increases. This way, after the observation period has passed, it would be possible to obtain an overall graphical representation of the user's motion statuses, as sketched in Figure 1.3.

The first insole prototype was implemented by using an Adafruit FLORA embedded board equipped with a Bluetooth Low Energy (BLE) transmission interface, and powered by a 9 V battery. The sensing element was a single Force Sensing Resistor (FSR) located under the heel, which enabled the possibility to count the steps performed by the user and identify the motion status. A picture of the embedded board and BLE interface is shown in Figure 1.4. The Adafruit FLORA board was programmed within the Arduino SDK environment by creating a proper *sketch* to collect the voltage values generated by the FSR sensor located under the heel, and associated to the steps performed by the user wearing the insole. By using the values generated by the sensor, and proper thresholds, the steps may be identified and counted, as well as the type of motion activity performed by the user, as the code extract provided in the following lines shows:

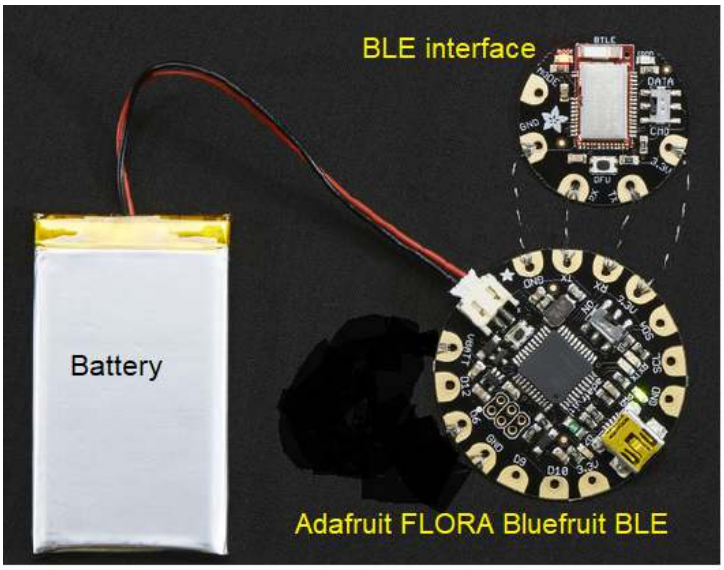


Figure 1.4: Flora Bluefruit board and BLE interface used to develop the first smart insole prototype.

```
#include <Adafruit_Circuit_Playground.h>

#define LOW_THRESH 512
#define HIGH_THRESH 1023
#define FSR_PIN 9

static boolean prevInRange = false;
long int count, i;
String string0 = "Not␣Worn";
String string1 = "Standing";
String string2 = "Walking";
unsigned long previousMillis = 0;
const long interval = 200;
const int N=15;

int contaPassi[N];
int valoriFSR[N];

void setup(void) {
    Serial.begin(9600);
    count=0;
    i=0;
}

void loop()
{
  int fVal;
  unsigned long currentMillis = millis();

  if (currentMillis - previousMillis >= interval){
   fVal = analogRead(FSR_PIN);
```

```
    count=conteggioPassi(fVal);
    contaPassi[i]=count;
    valoriFSR[i]=fVal;

    Serial.print(F("Steps:␣"));
    Serial.print(count);
    Serial.println();

    previousMillis = currentMillis;
    i=i+1;
    if(i==N){
     checkActivity(contaPassi[i-1], contaPassi[0],
                   contaPassi[i-6], valoriFSR[i-1]);
          i=0;}
    }
}


void checkActivity(int aN, int a0, int aN6, int v){
          if((aN-a0)>0){
             Serial.print(string2);
             Serial.println();
          }

          if ((aN==a0)&&(v<=LOW_THRESH)){
             Serial.print(string0);
             Serial.println();
          }

          if ((aN==a0)&&(v>LOW_THRESH)){
             Serial.print(string1);
             Serial.println();
          }

}

long int conteggioPassi(int fsrVal){
          boolean curInRange;
          if((fsrVal<LOW_THRESH)){
               curInRange = false;
          }
          if ((fsrVal >= LOW_THRESH) && (fsrVal <= HIGH_THRESH)) {
               curInRange = true;
          }

          if ((prevInRange == false) && (curInRange == true)) {
               count +=1;
```

```
        }

        prevInRange = curInRange;
        return count;
}
```

The output provided by the sketch running on the board is shown as an example in the following lines:

```
Thu Jul 25 00:07:08 CEST 2019 stepCounter=14, stepActivity=0

Thu Jul 25 00:07:08 CEST 2019 stepCounter=14, stepActivity=0

Thu Jul 25 00:07:09 CEST 2019 stepCounter=14, stepActivity=0

Thu Jul 25 00:07:09 CEST 2019 stepCounter=14, stepActivity=0

Thu Jul 25 00:07:09 CEST 2019 stepCounter=15, stepActivity=0

Thu Jul 25 00:07:09 CEST 2019 stepCounter=15, stepActivity=0

Thu Jul 25 00:07:09 CEST 2019 stepCounter=15, stepActivity=0

Thu Jul 25 00:07:10 CEST 2019 stepCounter=15, stepActivity=0

Thu Jul 25 00:07:10 CEST 2019 stepCounter=15, stepActivity=0

Thu Jul 25 00:07:10 CEST 2019 stepCounter=15, stepActivity=0

Thu Jul 25 00:07:10 CEST 2019 stepCounter=15, stepActivity=0

Thu Jul 25 00:07:10 CEST 2019 stepCounter=15, stepActivity=0

Thu Jul 25 00:07:11 CEST 2019 stepCounter=15, stepActivity=0

Thu Jul 25 00:07:11 CEST 2019 stepCounter=16, stepActivity=0

Thu Jul 25 00:07:11 CEST 2019 stepCounter=16, stepActivity=0

Thu Jul 25 00:07:11 CEST 2019 stepCounter=16, stepActivity=0

Thu Jul 25 00:07:11 CEST 2019 stepCounter=16, stepActivity=0

Thu Jul 25 00:07:12 CEST 2019 stepCounter=16, stepActivity=0

Thu Jul 25 00:07:12 CEST 2019 stepCounter=16, stepActivity=0

Thu Jul 25 00:07:12 CEST 2019 stepCounter=17, stepActivity=0
```

Figure 1.5 shows the three prototype insoles prepared for a first evaluation by Ana Aslan's team and delivered on July 31^{st}, 2019 during a visit to Bucarest by MPU. One of the three prototype insoles worn by a user is shown in Figure 1.6. The small pocket fixed on the ankle is needed to carry both the board and the 9 V battery used to power the electronics. An associated Android mobile app was also developed in order to connect to the insole by a BLE link, collect the data transmitted by the board and computed according to the code detailed above, and relay the data to the remote vINCI platform over a WiFi internet connection available through the smartphone.

Of course, this initial deployment was considered bulky and not usable by older adults, according to Ana Aslan's experts view and knowledge of the users' needs. Nevertheless, these three initial prototypes, with the associated app for the smartphone to collect data, were useful to prove the limits and feasibility of the initial idea, let the Ana Aslan team have a clearer idea of the issues and also realistic possibility to obtain data about the user's motion, and to design a minimally invasive wearable device.

Figure 1.5: The three prototype insoles delivered to Ana Aslan on July, 2019.

Figure 1.6: One of the three prototype insoles worn by a user.

Figure 1.7: Improved smart insole design.

Improved Smart Insole Design

Following the initial evaluations around the first prototype design of a smart sensorized insole, the most relevant requirements and critical constraints were collected:

- The insole should NOT require the user to wear anything applied on the ankle, in order to avoid causing potential problems during walking, possibly leading to a fall;
- The insole should be as much easy to use as possible, with minimal intervention requested to the user; it should be possible to wear the smart insole the same way as a *normal* one;
- The electronics onboard the insole should be less power demanding as possible, in order to allow the battery to be recharged not so frequently, and able to sustain the data transmission during usage;
- It is recommended to use a rechargeable battery, that should be possibly recharged by a USB cable, as it happens with most of modern battery-powered devices.

While, on one hand, requirements and constraints about the design of the smart insole emerged after the initial prototype tests, on the other hand, management problems related to project funding for the Italian partners determined difficulties in the deployment of a new design. For this reason, while the design and development of a new, improved version of the smart insole was started and undertaken, at the same time the Italian partners looked for a possible technological solution to avoid delays in the project development, and also to allow the partners in charge of the pilots to run their planned activities. Finally, an improved solution was found, in which the electronic components of the smart insole are almost embedded within it, the battery may be re-charged through a USB connection, and the data transmission happens on a BLE wireless link to a smartphone running a proper Android app. Figure 1.7 shows the new design of the smart insole, and Figure 1.8 shows how the new insole may be used within an existing shoe.

At the moment, one single FSR located under the heel is used to both count the steps performed by the user and also determine the motion status. Figure 1.9 shows the trend of the FSR signal generated during a walking session: red boxes identify each single step, while the green box collecting the initial samples identifies a standing condition.

Figure 1.8: How to wear and use the new smart insole.

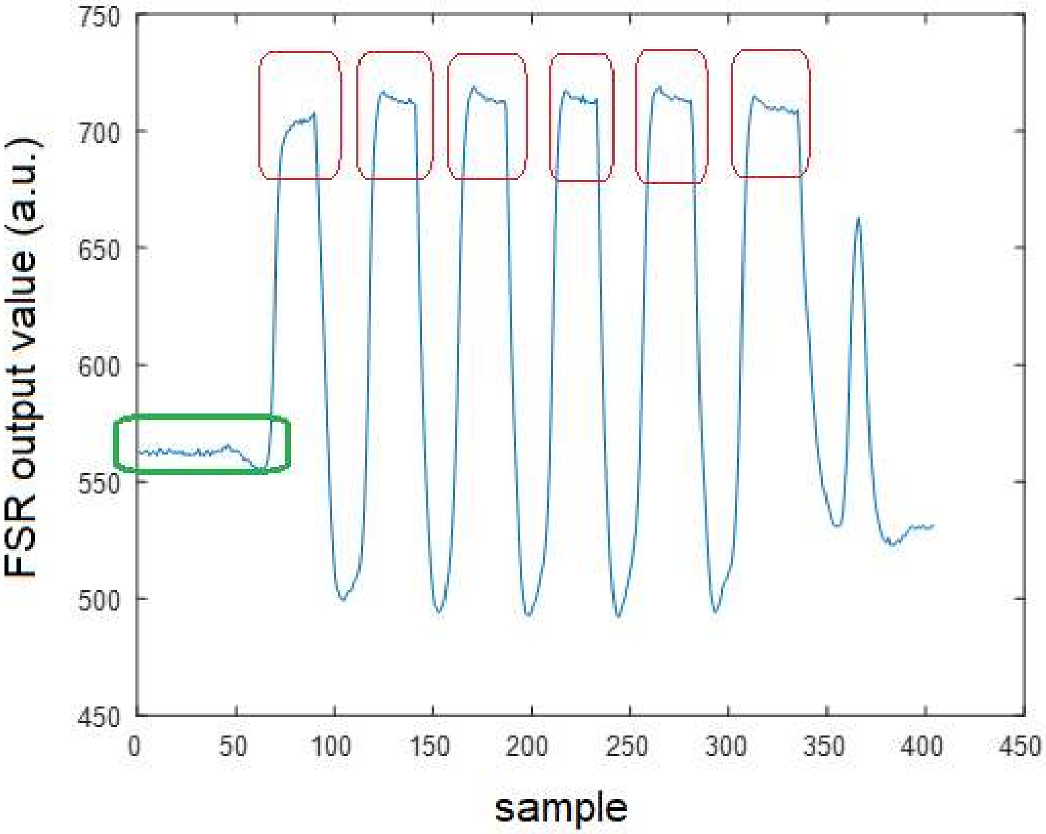


Figure 1.9: FSR signal and step identification.

1.4.2 Smartwatch

About the Smart Watch, the device, shown in Figure 1.10, is being produced by Connected Medical Devices (CMD). As such, the communication protocol between the watch and the CMD servers is proprietary and confidential (legal aspects mentioned explicitly by CMD). When a person buys the watch, an agreement is signed with CMD, so it is not possible to get into the normal communication flow between the watch and CMD's servers. This means, the person wearing the watch has to first install the CMD apk on a tablet or smartphone, which is the only mean to register that particular watch with the CMD servers (otherwise the data coming from the watch is not accepted, due to security reasons).

Figure 1.10: CMD smartwatch.

In order to connect the smartwatch data flow to vINCI, the *normal* flow implemented by CMD was accepted, and the developers agreed to work as a third entity: data is captured by the watch, sent to CMD's servers (where the CMD's apk is used for registration of the watch, for first-hand monitoring of data, for setting the geo-fencing and getting alerts), and from there, CMD exposes a REST API which the vINCI microservice calls to get the data (the frequency of such a request can be set as a parameter).

During the first tests and data transmission attempts, there were problems interpreting the data, as the development of the SW part is done by a different company. The communication problems are now solved, alerts and data can be correctly interpreted, and CMD can still filter privacy-relevant information. An example of the JSON received by the vINCI microservice is shown in Figure 1.11.

Data can be of two types: $H02-GPS$ and $H14-WiFi$ (a JSON translation is provided in vINCI for each type). The watch sends its current position in the $H02$ format if it has an active GPS connection, or in the $H14$ format, otherwise. Information sent includes IMEI, device ID, transmission date etc. The dedicated view in the vINCI's dashboard is now able to show the paths of people, geo-fencing, alerts, like shown in Figure 1.12.

1.4.3 Depth Cameras-Based Sensing

About the Depth Sensor, four Orbbec Persee cameras (`https://orbbec3d.com/product-persee/`) have been bought by ICI for the implementation of the pilot, as shown in Figure 1.13. Each device is a *camera-computer*, meaning it runs Android O.S., so it is possible to deploy local applications. Unfortunately, the device is not too computationally powerful, so it is not possible to run, for example, a face detection algorithm locally due to insufficient computing power.

Two applications have been developed:

1. Application 1, for detecting the activity of people within a room,
2. Application 2, to detect possible mobility problems.

They both exploit what the camera *sees*, which is shown in Figures 1.14 a) and b).

```
[
  {
    "_id":
    "5b19c84e807dd234f
    f805f4f", "ei":
    "352413080006397",
    "si": "9226103000013506",
    "dt": "2018-06-08T00:05:34.590Z",
    "s": "::ffff:109.166.135.51",
    "c":"#@H10@#;352413080006397;9226103000013506;862182;2018-06-
08;03:05:33;heart;\u0005;\u0001",
    "y": 2018,
    "m": 6,
    "d": 8,
    "p": "H10"
  },{
    "_id":
    "5b1b1496807dd234f
    f8064df", "ei":
    "352413080006397",
    "si": "9226103000013506",
    "dt": "2018-06-08T23:43:18.150Z",
    "s": "::ffff:109.166.135.133",
    "c":"#@H11@#;352413080006397;9226103000013506;862182;2018-06-
09;02:43:17;Shutdown;3;?;\u0001",
```

Figure 1.11: JSON data format generated by the CMD smartwatch.

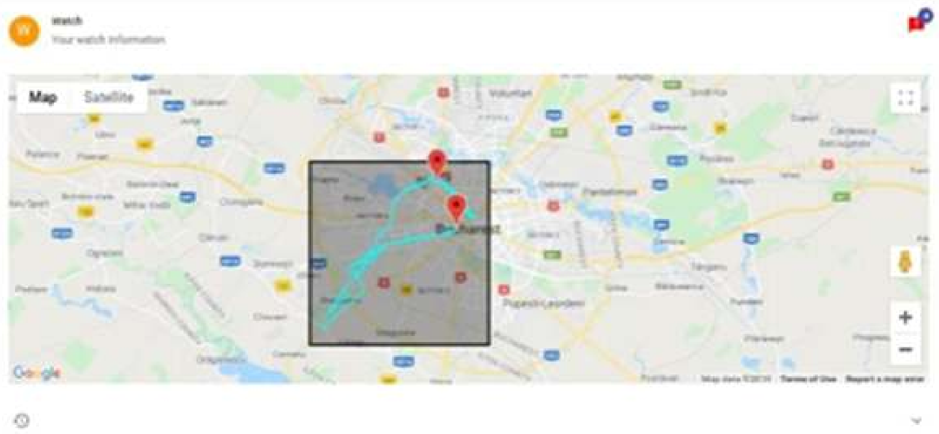
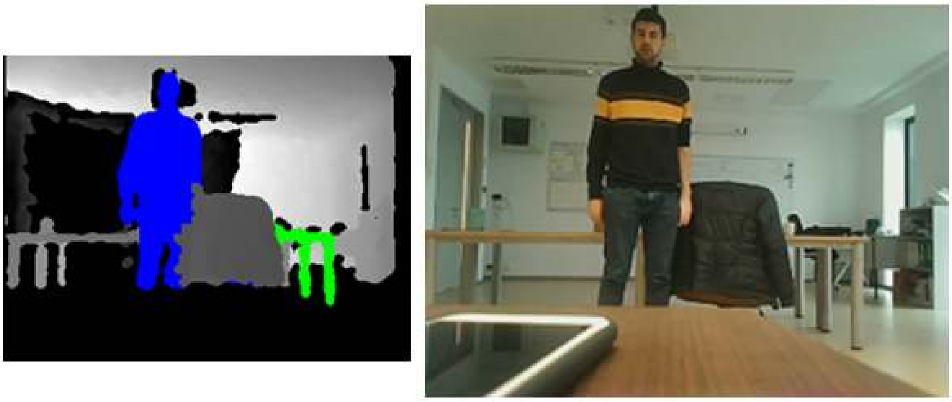


Figure 1.12: Graphic view of the data generated by the CMD smartwatch.

ICI team started developing Application 2 at the beginning of 2019. A first version was developed for Android O.S., using the Unity library. The application was showing an Avatar, which was performing a set of predefined (as in, for the moment, statically defined) set of exercises. The person in front of the camera (connected to a TV, where the apk is showing) was instructed to follow and replicate the movement of the Avatar. Using the depth sensor, it was possible to get the joints (skeleton) of the person, the objective being to find out possible activity-related problems (like symptoms of arthritis). A screenshot of the first version of this application is given in Figures 1.15 a) and b).

Figure 1.13: The Orbbec Persee depth camera used for the vINCI pilot.



a) b)

Figure 1.14: What the Orbbec Persee depth camera *sees*: a) depth frame, b) RGB frame, of the same scene.

a) b)

Figure 1.15: First generation of the Avatar application: a) the Avatar. b) the representation of the Kit within the Dashboard (superimposing the Avatar's vs. the Person's skeleton).

The only problem with the first version of this application was the speed of execution. Due to Unity, the application was really slow (the Orbbec camera itself has low computing power available). Naturally, different optimisation possibilities were tried, including the installation of Linux O.S. instead of Android (complete failure alltogether). So the application was fully re-engineered, into a version 2, Android-native one. For the second version, additionally ICI bought Nuitrack licenses (a powerful library equipped with validated routines for extracting data out of the depth sensors, for example). The application is based on Dalvik, which of course introduced an additional trick: to get the raw data from the Android-native routines all the way to the virtual machine. A first version was already demonstrated to Ana Aslan's pilot.

In this case, the problem is related to the synchronization between the Avatar and the user performing exercise: the Avatar performs the exercise, but the person can start simultaneously, or, in other cases, the person first watches the whole exercises and then she/he starts. The time difference between the Avatar and the person has to be *catched* dynamically (how to get this is currently under study). ICI team is now working on a request provided by the partner representing the users, i.e. Ana Aslan: the Avatar has to move with different speeds, a parameter which has to be set by the operator. Patients complaint they cannot cope with the normal speed, they don't get the details of the exercise. This is another aspect currently under development.

After this was done, the activities were focused on developing the Avatar logic. The 3D models needed are not easy to find on the market, and different combinations were tested, like getting the Avatars out of popular games to re-engineer them in our application. Right now, work is in progress on this application.

Actually, according to the DoW, the project was in need of Application 1 too, so the ICI team worked on this one, focusing on developing the apk able to extract data about the current activity the person is performing on a daily routine. This was developed to the point where it is possible to recognize the activity, but the more powerful part has to be done on-the-Cloud (again, the Orbbec device doesn't feature such a powerful processor). The routines to send the data to the vINCI gateway have been developed, and from there to the dedicated microservice. Two streams actually, and a JSON, are being transmitted. The two data streams correspond to the RGB-flow and the depth-flow, despite many technical issues related to the very poor quality of the WiFi connection available at Ana Aslan (a single, shared AP, is available). Now, for GDPR reasons, the RGB frames are sent to an in-memory processor on the backend, where we initially intended to perform the face-recognition, extract the ID of persons in the frame, and associate the data with the depth-frame (removing all-together the RGB data).

However, this didn't work either, as Ana Aslan specifically requested not to perform face recognition (which means they won't track the person's face, so face recognition cannot work). At present, a possible, feasible way to identify each patient by a different mean is being investigated. One Orbbec camera, together with a monitor (playing the role of the TV) was installed in the piloting room at Ana Aslan facility, as shown in Figure 1.16.

The problem that needs to be handled now is: if there are two vINCI apks, where will the camera (and the TV/monitor) be installed?. We first demonstrated the Avatar apk, and the camera was installed directly in-front of the person (on a small table). This was fine, but then for the activity-detection apk, the camera needs to be installed somewhere up. The person, for sure, cannot do the Avatar exercise looking at the camera (face up). We cannot assume someone would buy so many cameras, so we need to think of a solution where the TV is still in-front of the person, and the camera is somewhere up (the cable is not long enough, and the movement detection functions complicate a little). Different variations were tested also for the activity recognition apk. The problem is the limited coverage of the entire room, due to the existence of furniture (obstacles). A possibility relates to mounting a second Orbbec camera, but this introduces additional problems (correlating the depth frames between the sequence of cameras, to know we are looking at the same person) and increases costs. The camera in the pilot now communicates and transmits continuously to the vINCI backend microservice. We're using the data to develop the analytics. Additionally, the JSON with the joints (skeleton) of the person and those of the Avatar is being transmitted. One additional problem is: we need to include into the operation rules that the cameras (and the WiFi booster for the matter) are not to be disconnected from their electric outlets (this happened, especially during the change of the patients being hosted there).

Figure 1.16: Orbbec deployment in the pilot room at Ana Aslan facility.

1.4.4 First Operational Protocol to Run the Pilots

A first setting of one of the two forseen pilots has been implemented in Ana Aslan Institute (Bucharest, Romania). Following the very first experience of setting the Ana Aslan pilot, which is not fully-functional yet (the smartwatches are not worn by the users - they are in the testing phase - and this is also valid for the smart insoles, for which a BLE-enabled communication module is needed, and the tablets are not available for this), it is possible to summarise the following considerations:

1. An operator has to be dedicated to the activities related to the use of vINCI technologies, preferably someone from the medical personnel.
2. The operator has to know the real identity of the hospitalized patients (they tend to change every week). For each patient, an account in the vINCI dashboard has to be created by the operator (when the patient is first admitted into the experiment, for example). This real identity of the patient needs to be kept only by the operator, and the platform works with virtual associations. This means that also the operator needs to register the physical smartwatch into the patient's profile, or the virtual identity being used by the questionnaire.
3. At 9:00 AM each morning, the operator comes and takes one of the tablets available in the room instrumented for the pilot (tablets need to stay there to act as communication relays always). The operator opens the questionnaire apk. The first screen allows to select one of five identities (no login required, as this is a virtual association alone with the real patient's name). Then the operator selects the WHOQOL questionnaire and assists the patient into filling in the data. In the real-world situation, we assume non-hospitalised patients are able to fill in this by themselves.
4. If the computed score, at the end, is positive, that's all for the day. Otherwise, the operator will assist the patient with the other two questionnaires.
5. At the end, the operator puts the tablet back. Then, the operator asks the first patient to do some exercise in front of the TV (following the Avatar). Here, the operator opens the apk (this time, running on the Orbbec's Android O.S.) for the Avatar apk and selects the virtual identity

of the patient (out of five). Each patient should have a pre-selected set of exercises (tailored to their particular conditions) – this has to be defined by the operator or the medical personnel in the dashboard, linked with the particular profile of that patient. Now, the Avatar starts. The speed can be changed by the operator, guided by the patient. The patients move following the Avatar's indications. At the end, the operator exits the patient's profile, and opens another way (inviting the next patient to start their set of exercises, associated with that person's virtual identity).

6. The operator checks once more that the patient is wearing the smart watch and smart insole, and the camera is connected to the electric outlet. For verification, the operator can even check the patient's profile and see if data is being captured.
7. Only now the operator leaves. The patients remain on-their-own, performing their normal daily routines.
8. During the day, the smart isoles send data to the tablets, and from there to the specific microservice. The same for smart watches, and the camera detecting the activity. All the data is being processed by their corresponding microservices, and the resulting information is being aggregated by the I/O microservice into the patient's profile.
9. Phase 2 of the pilot will include the possibility for doctors to also cross-examine the patient (medical examinations). The data has to be also incorporated into the platform, from where it has to be used by reinforced machine learning algorithms in the construction of appropriate patient models. These models are constructed and used as inference models in the end for anomaly detection algorithms (to detect a significant deviation of the patient's *usual* conditions).
10. One thing is that, periodically (usually on Friday), the patient is asked by the operator to fill in also the user needs and feedback questionnaires. This means we also want to know the patient's impression of the technology (use, feel, significance over personal life, etc.), but also to get first-hand impressions about some aspects which can be improved (such as the possible lack of some functions the user felt like missing and would have like to be included in the technology).

Chapter 2

Room Kit (TBC)

2.1 Aimed Service and Requirements

Within the vINCI project, a ***kit*** is intended as a different variant of coupling the services supported by the platform, each time targeting a particular caregiving and healthcare need.

The Room kit focuses on monitoring the user's behaviour inside a room, and it includes activity monitoring using depth sensors and identifying motion patterns. The Room Kit facilitates the profiling of older adults with respect to the consistency of their daily routine and the identification of abnormalities. It tracks location and movement data, which can be helpful to determine falls, walking or posture problems, etc. Changes in movement patterns or in the amount of physical activity during a day can also be indicative of the onset of cognitive or neurodegenerative disorders. Simple indicators such as the amount of time spent in a room, the (successful) completion of exercises or routines are all significant metrics of independence. Automated reporting of these behaviours to carers can also mitigate the burden of checking up this information about the daily routine. The challenges of this kit are to minimize the need by older adults for external intervention, and to minimize false alarms. Such a passive monitoring capability is a need not covered by the market yet.

2.2 Room Kit Components

The hardware and software components of the Room Kit are those related to the Depth Cameras used indoor and the corresponding two application being developed:

1. Application 1, for detecting the activity of people within a room,
2. Application 2, to detect possible mobility problems.

The camera currently installed in the pilot communicates and transmits continuously to the vINCI backend microservice. Data are being used to develop the analytics. Additionally, the JSON with the joints (skeleton) of the person and those of the Avatar is being transmitted, to enable the implementation of services aimed at monitoring the user's physical abilities when performing exergames in front of the Depth sensor.

The development of Depth-based monitoring also includes the possibility to use a second sensor, located on the room ceiling, in order to monitor the mobility patterns of a user inside the room. By processing the stream of Depth frames captured by the sensor, it is possible to identify the blob of the human subject from the top view and locate its position on a 2D-plane. This way, checking the position occupied by the subject during a given amount of time, and based on the *a priori* knowledge of what is in the physical area covered by the sensor (e.g. a sofa, a table, a kitchen corner), it is possible to estimate how much time the subject spent in a given activity (e.g. sitting on the sofa – sedentary behavior, cooking – autonomous behavior, etc etc). The *a priori* information about what is included in the area covered by the depth sensor, and the extraction of sensible information from the data generated by the sensor, are in charge of the application that will run on the remote server and elaborate the raw data generated by the monitoring system.

2.3 Room Kit Integration

In each one of the kits envisioned by the vINCI project, integration takes place at the server side, i.e. on the remote platform where microservices are running and process the data generated by the sensing technologies used in each kit.

In the context of the Room Kit, the integration among sensors' data will allow to develop the two applications mentioned in the previous section, aimed at providing information about the physical and cognitive conditions of the user, to support both independent living, anticipated recognition of possible decline, and also improved caring by a professional caregiver or healthcare provider.

The analysis and modelling of the captured information, using different techniques can provide descriptions about lifestyle, changes in clinical and behavioural dynamics of the patient and other complex information about each person. The data analysis will lead to lifestyle description, information about changes in clinical and behavioural dynamics of the patient. This analysis allows the building of formal model of the patient's lifestyle and of the patient's behavioural, clinical and biological dynamics, which will be integrated in the computer-based systems. This contributes to improve the diagnosis and management of geriatric syndrome in primary care, as well as to increased levels of wellbeing, QoL and perceived health. For vINCI care, the patient profile will be the input to provide personalized support for daily / medical activities. Finally, the patient profile will be used as evidence to evaluate the impact of vINCI on the perceived QoL level, allowing a proper adjustment (if needed) of the intervention support being provided by caregivers.

Chapter 3

Activity Kit (TBC)

3.1 Aimed Service and Requirements

Within the vINCI project, a ***kit*** is intended as a different variant of coupling the services supported by the platform, each time targeting a particular caregiving and healthcare need.

The Activity kit is designed to gather data associated with activity recognition. This includes tracking activities and whereabouts associated with older adults in outdoor scenarios, using either smart watches or shoes, or opportunistic contacts through RFID or BLE technology. For indoor, a TV with an integrated depth sensor will monitor activities, including fall detection, gait, and the accuracy of prescribed exercises. This kit provides higher resolution to the room kit on specific activities.

3.2 Activity Kit Components

The Activity Kit builds upon the aggregation between the smart isole, the smart watch and the indoor activity tracker implemented by means of the Room Kit (to find how much activity the person is performing).

The wearable, minimally intrusive smart insole is able to somehow *measure* the activity levels of an older adult, by evaluating the following target metrics:

- number of steps performed during an observed amount of time;
- mobility *status* associated to three different conditions, i.e. standing, walking, not wearing the insole, monitored within a specified time interval (every 3 seconds), in order to provide a more detailed report about the motion activity of the user overall the observed time.

The smart insole is designed as a sensing device equipped with a force sensor (Force Sensing Resistor - FSR) and embedded electronics. The force sensor is used to detect, by means of a proper software application running on the embedded board, the three different activity statuses detailed above.

The smartwatch will send information to Connected Medical Devices Platform and Connected Medical Devices will export in the form of a JSON the following data for each smartwatch:

- GPS Location/time
- Number of steps
- Battery
- Times the watch exits the defined zone (geofencing)
- Times that the watch was taken down from the hand.

This information is sent encrypted to the VINCI platform in order to be interpreted.

3.3 Activity Kit Integration

The physical activity of the user will be objectively evaluated based on the data collected from the smart insole which will measure the daily number of steps and, as a possible second-order functionality, a median gait speed. Obtaining the gait speed would provide a simple yet very important parameter for early identification of functional decline. When the gait speed falls below a predefined value, the user could receive a specific feedback, possibly also on the tablet screen.

The vINCI technology will also offer the possibility of identifying the user's exact location with the smartwatch. If the user has fallen and/or is unable to call for help or if the user is disoriented, the identified caregiver can be notified of the situation.

The analysis and modelling of the captured information, using different techniques can provide descriptions about lifestyle, changes in clinical and behavioural dynamics of the patient and other complex information about each person. The data analysis will lead to lifestyle description, information about changes in clinical and behavioural dynamics of the patient. This analysis allows the building of formal model of the patient's lifestyle and of the patient's behavioural, clinical and biological dynamics, which will be integrated in the computer-based systems. This contributes to improve the diagnosis and management of geriatric syndrome in primary care, as well as to increased levels of wellbeing, QoL and perceived health. For vINCI care, the patient profile will be the input to provide personalized support for daily / medical activities. Finally, the patient profile will be used as evidence to evaluate the impact of vINCI on the perceived QoL level, allowing a proper adjustment (if needed) of the intervention support being provided by caregivers.

Chapter 4

Biomarkers Kit (TBC)

4.1 Aimed Service and Requirements

Within the vINCI project, a ***kit*** is intended as a different variant of coupling the services supported by the platform, each time targeting a particular caregiving and healthcare need.

The Biomarkers Kit was intended to passively monitor user's biomarkers (e.g. blood pressure, heart rate, etc.). Real-time tracking of biomarkers can reveal significant life changing events and track general health and wellbeing over time.

4.2 Biomarkers Kit Components

An initial analysis of the state-of-art devices and technologies possibly available for integration with the vINCI platform showed that the idea of setting up a Biomarker Kit has a quite relevant complexity. In fact, some tests were performed trying to integrate a Galvanic Skin Response sensor into the system, in order to catch the stress level of the user, but it was not accepted by the test users, who felt both physical and emotional discomfort. The point about the Biomarkers Kit will need additional investigations.

4.3 Biomarkers Kit Integration

The possibility to effectively set up a Biomarkers Kit, and how to integrate the different metrics provided by possible measurement devices will be address in the next months of project activities.

Chapter 5

Social Kit

5.1 Aimed Service and Requirements

Within the vINCI project, a ***kit*** is intended as a different variant of coupling the services supported by the platform, each time targeting a particular caregiving and healthcare need.

The Social kit detects the co-location of older adults with other vINCI actors, devices, locations and selected third party services. It can act as a remote version of the Activity Kit for outdoor scenarios. It can be very revealing of the older adult symptomatic problems, as a socially inactive person could mean an early sign of depression. The Social Kit can reveal if older adults have a support network and experience (positive) social interactions or if they are isolated and lonely. The presence of a *large* social network does not necessarily imply the presence of a confiding relationship or the absence of loneliness (and vice-versa) for older adults living at home or in a nursing home, thus viewing the network alone is not sufficient.

For the social dimension of QoL, applications to support older adult social interactions (i.e. common Facebook groups) can be recommended. This Kit will track and unobtrusively observe the social patterns of older adults to ensure that they stay connected to, and engage with, friends, relatives, the local community, and their carers.

5.2 Social Kit Components

The hardware and software components of the Social Kit are an aggregation of those related to the Depth Cameras used indoor and the smartwatch used within the Activity Kit.

The data provided by the Depth cameras may be exploited to understand if the user as a sedentary behaviour or he/she is maintaining an adequate level of physical activity, which also provides evidence of a good mental and emotional status. Data generated by the smartwatch may be exploited to understand, first of all, if the user spends time outside his/her home, of he/she keeps performing external activities (like taking a walk, going groceries, etc). Additionally, it is possible to track how much distance the user is able to travel and if he/she is able to get back home. All these metrics may provide some insights about the level of social interactions of the user.

5.3 Social Kit Integration

The Social kit is the aggregation between the camera-monitoring activity tracking (or, tracking here the sedentariness level) coupled with the smartwatch monitoring (for detecting external activities, distance travelled, possible loss of memory..).

The analysis and modelling of the captured information, using different techniques can provide descriptions about lifestyle, changes in clinical and behavioural dynamics of the patient and other complex information about each person. The data analysis will lead to lifestyle description, information about changes in clinical and behavioural dynamics of the patient. This analysis allows the building of formal model of the patient's lifestyle and of the patient's behavioural, clinical and biological dynamics, which will be integrated in the computer-based systems. This contributes to improve the diagnosis and management of geriatric syndrome in primary care, as well as to increased levels of wellbeing, QoL and perceived health. For vINCI care, the patient profile will be the input to provide personalized support for daily / medical activities. Finally, the patient profile will be used as evidence to evaluate the impact of vINCI on the perceived QoL level, allowing a proper adjustment (if needed) of the intervention support being provided by caregivers.

List of Figures

1.1 vINCI collecting platform scheme and data flow diagram. 3

1.2 Optima Molliter's YDA footwear. 5

1.3 Possible representation of a user's motion statuses overview. 6

1.4 Flora Bluefruit board and BLE interface used to develop the first smart insole prototype. 7

1.5 The three prototype insoles delivered to Ana Aslan on July, 2019. 10

1.6 One of the three prototype insoles worn by a user. 10

1.7 Improved smart insole design. 11

1.8 How to wear and use the new smart insole. 12

1.9 FSR signal and step identification. 12

1.10 CMD smartwatch. 13

1.11 JSON data format generated by the CMD smartwatch. 14

1.12 Graphic view of the data generated by the CMD smartwatch. 14

1.13 The Orbbec Persee depth camera used for the vINCI pilot. 15

1.14 What the Orbbec Persee depth camera *sees*: a) depth frame, b) RGB frame, of the same scene. 15

1.15 First generation of the Avatar application: a) the Avatar. b) the representation of the Kit within the Dashboard (superimposing the Avatar's vs. the Person's skeleton). 15

1.16 Orbbec deployment in the pilot room at Ana Aslan facility. 17