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Abstract	This report documents the status of development of the Smart applications in the City, Security and Health scenarios along with the trials performed for each.
Keywords	FIWARE, Smart City, Smart Healthcare, Smart Security

Document Revision History

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Nature of the deliverable:	R	
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PU	Public, fully open, e.g. web	✓
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CO	Confidential to SmartSDK project and Commission Services	

** R: Document, report (excluding the periodic and final reports)*

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

OTHER: Software, technical diagram, etc.

EXECUTIVE SUMMARY

SmartSDK delivers a set of applications in the Smart City, Smart Healthcare, and Smart Security domains. Such applications are based on: components (i.e. Generic Enablers and Specific Enablers), data models (i.e. NGSI formalisation of the data exchanged among components) and reference architectures (i.e. the combination of components and data models to support production grade requirements).
This document describes an overview of the objective application, main functionalities, reference to manuals (English and Spanish version), and results of the trails performed for each application in the following three scenarios:

- Monitoring pollution and traffic in cities (Smart City);
- Mobile sensing of health parameters (Smart Healthcare);
- Intelligent video surveillance in parking and buildings (Smart Security);

The architecture of the applications and details on their modularity can be found in D2.5 “Reference architectures for data-intensive and IoT-based Smart City, Smart Healthcare and Smart Security applications” [5], whereas D3.4 “SmartSDK Reference Models and Recipes” [6] provides insights on the adopted data models.

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ABBREVIATIONS

CO	Carbon Monoxide
GUI	Graphical User Interface
LwM2M	Lightweight Machine to Machine
NO2	Nitrogen Dioxide
O3	Ozone
PM10	Particulate Matter
SDK	Software Development Kit
SO2	Sulfur Dioxide

1 INTRODUCTION

This document presents the reference material for the applications developed by the SmartSDK project in the Smart City, Smart HealthCare and Smart Security domains. For each application, the objective and background are described, the main functionalities are discussed and pointers to the reference manuals, in English and Spanish, are also presented. Finally, the results of the trials for those applications are described in this document.

The Smart City, Smart Healthcare and Smart Security applications are based on the Generic Enablers provided by FIWARE, the data models, architecture patterns and specific enablers developed as result of the SmartSDK project.

1.1 Structure of the deliverable

The deliverable is structured as follows:

- Section 2 presents Green Route, a Smart City application focusing on monitoring pollution and traffic congestion for smart cities to better plan routes.
- Section 3 presents Mobility Assessment Test, a Smart HealthCare application for mobile sensing along with two other applications developed for the HealthCare scenario.
- Section 4 presents ViVA, a Smart Security application for intelligent video surveillance.

1.2 Audience

This deliverable is mainly intended for:

- Developers looking for replicable examples of FIWARE Smart applications.
- Developers interested into adopting FIWARE or contributing to the initiative.

2 SMART CITY APPLICATION

2.1 Introduction

This section presents the Smart City application, which focuses on monitoring pollution and traffic congestion. In the application the user is able to select a route and visualize pollution, traffic and weather information near to the selected route. In Figure 1 the *Plan my trip* interface of the Green Route is shown.

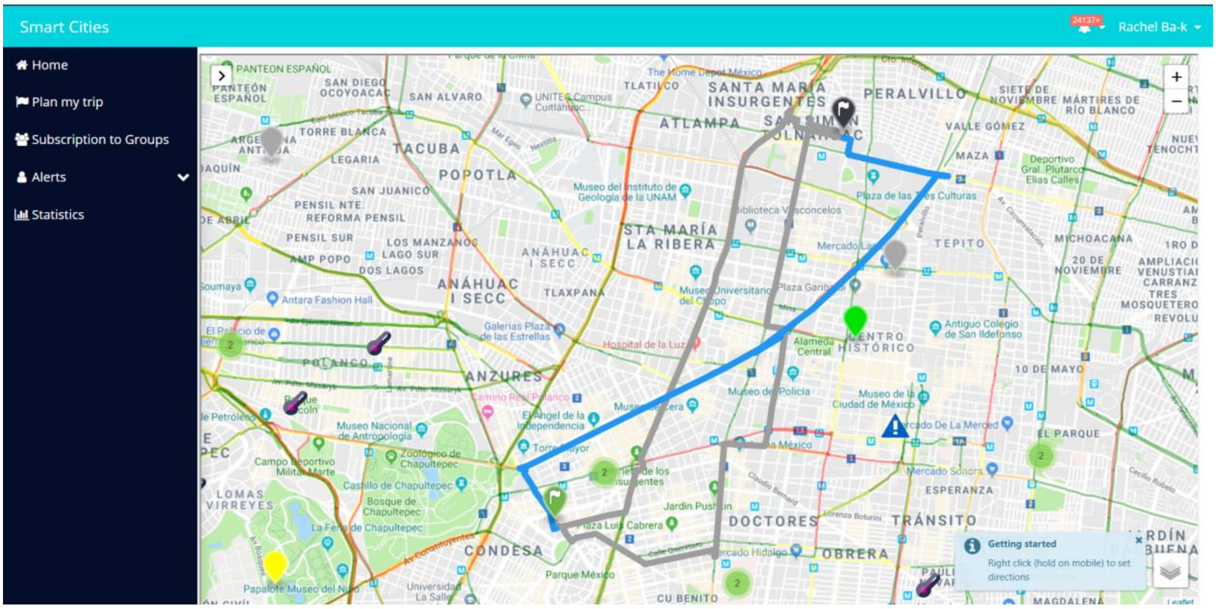

Figure 1: Green Route Interface

2.1.1 Background

The population living in cities increase every day. In this sense, since this century, half of the population in the world live in urban areas compared with 15% that lived in cities one hundred years ago. The increase in the world's urban population, from two hundred million to almost 3 billion in only one hundred years is a clear indication of a lot of people moving from rural areas to urban centres and also an increase in the number of people born in cities [1].

If we combine these data with the fact that the area that is urban has only grown to the 2.8% of the total land area of Earth, it is a clear indication of overpopulation in several cities. Usually, many ecosystems in and around urban areas are more biodiverse than rural monocultures; however, as cities grow in size, they start suffering from increased congestion, higher crime rates and air pollution. Usually cities suffer to manage energy, mobility, environment, services, waste, living places, logistics, health, security, etc. The financial and human resources needed to support cities are immense.

In this context, new innovative solutions to old problems of cities are needed. We consider that SmartSDK will provide a good solution for some mobility issues in most of the cities in the world.

2.1.2 Objective of the application

The application developed in the Smart City domain (called Green Route) focuses on supporting the citizen mobility in high-polluted cities, like Mexico City, with the aim of improving the life quality of citizens and fostering environmentally-friendly behaviours by citizens.

The objective of Green Route is to help the final user to determine the best route to follow to reach a destination, taking into account the user profile (such as health conditions), the user preferences (such as transport type), as well as the weather and pollution of the city.

This application will improve the experience of the user to plan a trip according to their own profile conditions and the context data.

2.1.3 Main functionalities of Green Route

The list of functionalities of the Green Route application for users, transport managers and super-users is presented below.

Functionalities for end users:

- **User account management:** In this functionality, we have the options for user management. In the case of a new user, this is the section to indicate their personal data. In the case of health profile, in this moment we have 3 options about the current state of health of the user, *good*, *allergy* (where the user can select symptoms of this disease) and *asthma* (where the user can select the rate of severity of the disease). In this section, the user can also introduce the basic information of their vehicles.
- **Subscriptions to alerts by groups:** This functionality covers the subscriptions to one or multiple groups. This subscription is needed to receive alerts that are relevant for the group. For example, the Biker group is related to alerts for traffic jam, accidents, and weather conditions.
- **Alerts management:** The alert module allows to user for generating geo-located alerts about asthma attacks, traffic jam, accidents, weather conditions, high level of pollution, or presence of pollen. The alert that can be placed by using the smartphone and the system will take the location of the situation.
- **Plan your trip:** This functionality is related to the selection of the destination to reach, indicating the different alternatives of public transport.
- **Air quality monitoring:** This functionality displays, in a map, the information of air quality units of Mexico City. For instance, the information is related to temperature, relative humidity, O3, NO2, PM10, SO2, and CO.
- **Real-Time Traffic Information:** This functionality displays, in a map, the information about traffic in Mexico City.
- **Time Series Information:** This functionality allows to the user visualize the information of air quality units represented in graphics by using tools like Grafana, CrateDB and QuantumLeap.
- **Pollen information:** This functionality displays, in a map, the information of pollen in some areas of Mexico City.

Functionalities for public transport manager:

- **Public transport management:** This functionality manages the information related to the vehicle assigned as public transport. It is necessary to add data related to total number of passengers, name, fuel type and other information related to the vehicle. Besides, a vehicle should be assigned a transport schedule.
- **Transport schedule management:** This functionality is for adding, editing or updating a transport schedule. The manager indicates the route name, and the departure and arrival time for each day. In addition, the manager could indicate if the schedule is activated or not.

Functionalities for super-users:

- **Group management:** This functionality is only for the super-user and it consists of creating, editing, updating and deleting a group to receive alerts. In this way, an end user can receive real time alerts from weather conditions, pollution, traffic, and so on from other users. In order to receive alerts, the end users should subscribe to one or multiple groups, according to their preferences.

- **User manager tray:** This functionality is related to the creation of new users by a super-user. In this way, the super-user can create a public transport manager or end user. In addition, the functionality allows editing, updating or deleting a user.

2.2 User Manuals

User manuals have been created in both English and Spanish to explain the main functionalities of the application. Having the manuals in both languages helps increasing the propagation of the application to users in Mexico and Europe. We know that providing manuals in Spanish could boost Mexican users to try the Green Route application. Additionally, Docker images of the application and a reference guide to deploy the application from source code is available from the SmartSDK GitHub repository.

- The link for documentation in English is the following:
  - https://green-route-manual.readthedocs.io/en/latest/
- The documentation in Spanish is the following:
  - https://green-route-manual-es.readthedocs.io/es/latest/
- Docker Deployment Guide from source codes:
  - https://github.com/smartsdk/greenroute-backend/tree/master/src/main/docker
- The docker images are the following:
  - https://hub.docker.com/r/smartsdk/greenroute-front/
  - https://hub.docker.com/r/smartsdk/greenroute-back/
  - https://hub.docker.com/r/smartsdk/mongo-seed/

2.3 Trial Planning

This section describes a test plan designed to conduct a usability test of the Green Route application. The main test objective was to determine design inconsistencies and usability problem areas within the user interface and content areas. Potential sources of error may include:

- Navigation errors – failure to locate functions, excessive keystrokes to complete a function, failure to follow recommended screen flow.
- Presentation errors – failure to locate and properly act upon desired information in screens, selection errors due to labelling ambiguities.
- Control usage problems – improper toolbar or entry field usage.

In the usability test, at least five participants were expected to be testing the Green Route Application during a small session where time would be recorded for each participant. Green Route is not focused on a specific kind of final users. To participate in the tests, users needed to be over legal age (with a valid id document) and possess a mobile device Smartphone/Tablet (no specific Operating System needed) with GPS and web browser.

2.3.1 Methodology

During the trial, participants were required to use the Green Route Application to introduce their personal data. These data remained in local databases and secured through the FIWARE authorization mechanisms. Therefore, no personal data were sent to the FIWARE Cloud and remained secure in local databases.

The plan was to recruit at least five participants for the test; all of them could be together in one session or divided into several individual sessions. Each session lasted approximately 30 minutes. Participants received an overview of the usability test procedure in order to complete a set of representative task scenarios and provide feedback regarding the usability and acceptability of the user interface. Finally, the participants were asked to provide honest opinions regarding the usability of the application, and to participate in post-trial questionnaires and debriefing.

Participants took part in the usability test at INFOTEC and ITESM in Mexico City. A Smartphone with Internet access and GPS were used as in a typical daily environment.

The session scheduling plan was as follows:

Beginning of session:

- The facilitator will brief the participants on the system and instruct the participant that they are evaluating the application, rather than the facilitator evaluating the participant.
- The purpose of the trial was explained to the participants and the facilitator asked participants to sign the consent form as well as to fill out a brief background questionnaire.
- The participants signed the consent form that acknowledges the participation is voluntary and that they would complete a background questionnaire.
- The participants received an overview of the test procedure -including the tasks to perform explained in the next section-, and the printed questionnaires that they need to fill out during the trial. A brief period of time to attend doubts and questions from participants was considered.

During the session:

- The facilitator requested participants to perform the tasks described in the Task specification document.
- Participants had to execute the specified tasks in the Task specification document.
- The participant's interaction with Green Route Application was monitored by the facilitator with the aim of measuring the time of each activity and size the difficulties during the test.
- After each task, the participants had to complete the after-task questionnaires to evaluate the task.

Ending of the session:

- The post-task questionnaires were gathered.
- Participants had to rate the application overall through a general usability questionnaire. Additionally, recommendations for improvement were asked.

2.3.2 Usability tasks

The usability tasks were derived from test scenarios developed from use cases and with the assistance of a subject-matter expert. The tasks were identical for all participants in the study.

- **Task 1. User registration and Login.**

  User should be able to register and to login in the Green Route Application.
- **Task 2. Change the password.**

  User should be able to change its password.
- **Task 3. Password recovery.**

  User should be able to recover its password.
- **Task 4. Edit user profile.**

User should be able to edit its profile.

- **Task 5. Edit health profile.**

  User should be able to edit its health profile.

- **Task 6. Edit vehicle profile.**

  User should be able to edit its vehicle profile.

- **Task 7. Subscribe to groups and visualize alerts.**

  User should be able to subscribe to groups and visualize alerts that belong to the group in which the user is subscribed.

- **Task 8. Generate alerts.**

  User should be able to generate alerts.

- **Task 9. Plan trip.**

  User should be able to select a route and visualize relevant information about the selected route.

2.4 Results of the trial

This section describes the results of the trial of Green Route. The results are presented through graphics, which concentrate the collected information of the after-task questionnaires applied to the participants during the trial.

2.4.1 Participation for the trial

Green Route was not focused on a specific kind of final users. There were no requirements of previous knowledge about similar systems or computational skills. The only restrictions were: the participants in the tests must be over legal age and have a mobile device Smartphone/Tablet (no specific Operating System needed) with GPS and web browser.

During the trial, a group of 18 participants from INFOTEC and ITESM were recruited to perform the usability test of Green Route. The application of the usability test was carried out in INFOTEC and ITESM in Mexico City. During the test, participants were required to execute the usability tasks listed in the previous section (2.3.2).

The trial was carried out according to the schedule defined in the section 2.3 Trial planning. The participants received an overview of the usability test procedure in order to complete a set of representative task scenarios and provide feedback regarding the usability and acceptability of the user interface. Finally, the participants were asked to provide honest opinions regarding the usability of the application, and to fill out an *after-task questionnaire* for each task and a final usability evaluation questionnaire.

2.4.2 After-task questionnaire

The after-task questionnaire consisted of five questions set to evaluate the different aspects of the usability of Green Route. The five questions and aspects evaluated were the following:

- **Question 1. How easy was to complete the task?**

  Aspect evaluated: Level of facility to complete a task.

- **Question 2. Understand the activities that were carried out to complete the task was:**

  Aspect evaluated: Ease of understanding to perform the task

- **Question 3. To complete the task, did you require prior learning or detailed explanation**

of the use of the application?

Aspect evaluated: Level of prior learning to complete the task.

- **Question 4. How did you identify each element on the screen and its functionality?**

  Aspect evaluated: Fast identification of the elements of the application and its functionality.

- **Question 5. Do you think the navigation in the application was practical and understandable to complete the task?**

  Aspect evaluated: Level of intuitiveness of the application.

The tasks evaluated are the following:

- **Task 1. User registration and Login**
- **Task 2. Change the password**
- **Task 3. Password recovery**
- **Task 4. Edit user profile**
- **Task 5. Edit health profile**
- **Task 6. Edit vehicle profile**
- **Task 7. Subscribe to groups and visualize alerts**
- **Task 8. Generate alerts**
- **Task 9. Generate route**

The following graphics illustrate the results of every task in each question:

Question 1. How easy was to complete the task?

According to the results, show in Figure 2, task 9 (Generate route) was the most difficult to complete followed by task 8 (Generate alerts). In the other tasks, almost all the users specified that the tasks were very easy or easy to complete.

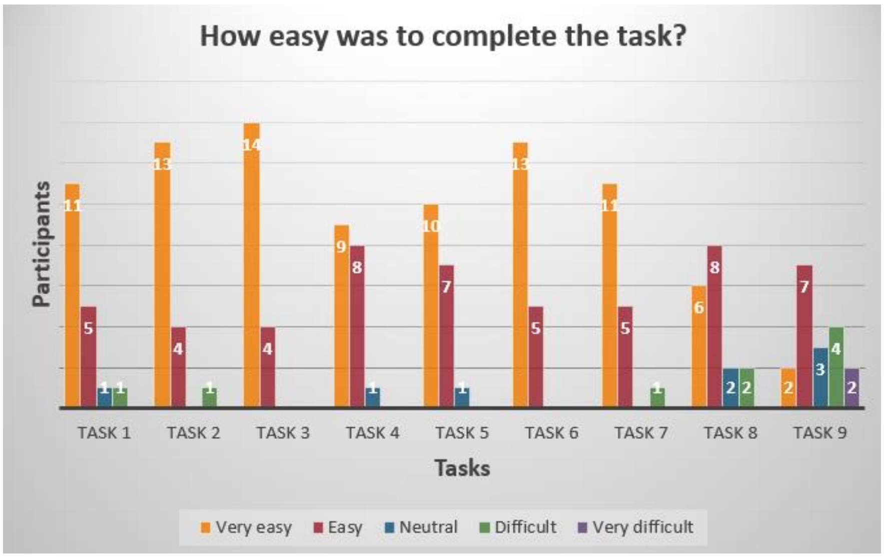

Figure 2: Results of question 1: How easy was to complete the task?

Question 2. Understand the activities that were carried out to complete the tasks was:

As shown in Figure 3, the task 9 (Generate route) was the most difficult to understand followed by the task 8 (Generate alerts). In the other tasks, almost all the users specified that the tasks were very easy or easy to understand.

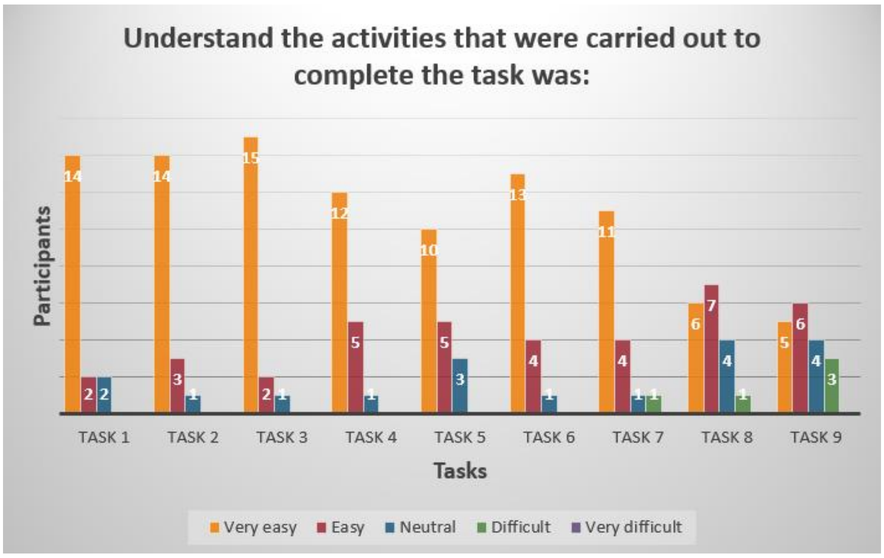

Figure 3: Results of question 2: Understand the activities that were carried out to complete the task

Question 3. To complete the task, did you require prior learning or detailed explanation of the use of the application?

As it can be seen in the plot of Figure 4, in the task 9 (Generate route) participants expressed that prior learning or detailed explanation was required to use the application, followed by the task 8 (Generate alerts). In the other tasks almost all the users specified that no prior learning or detailed explanation was needed.

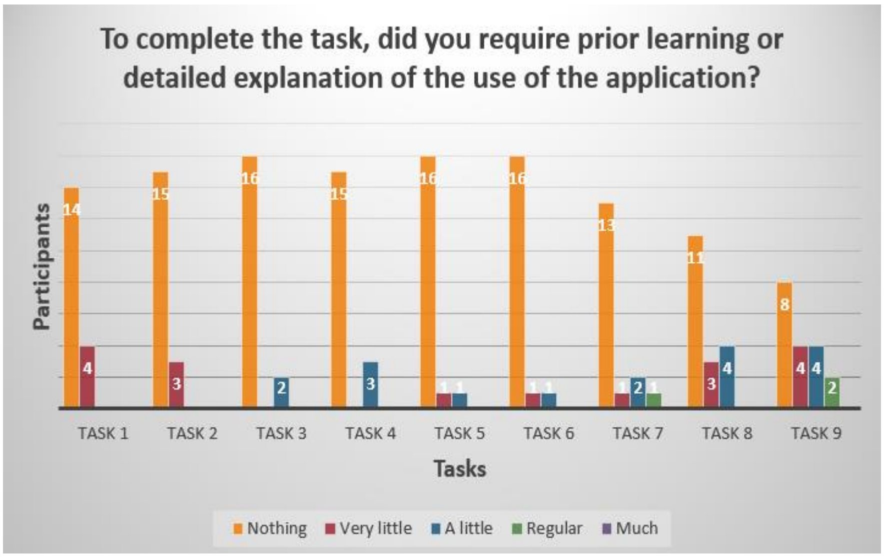

Figure 4: Results of Question 3: To complete the task, did you require prior learning or detailed explanation of the use of the application?

Question 4. How did you identify each element on the screen and its functionality?

As shown in the graphic, in the task 9 (Generate route) participants revealed that more time is required to identify the elements and its functionality, followed by the task 8 (Generate alerts). In the other tasks almost all the users specified that the elements and its functionality can be identified very fast or fast. Results are shown in Figure 5.

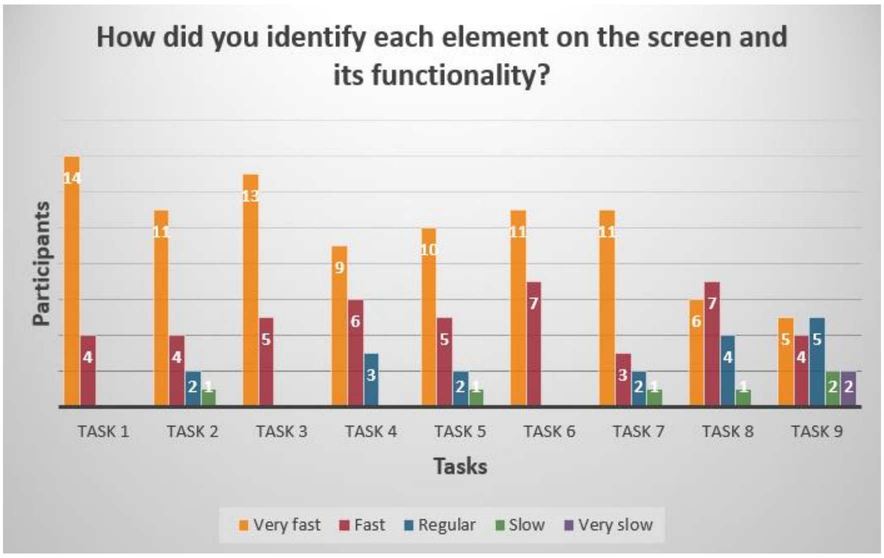

Figure 5: Results of question 4: How did you identify each element on the screen and its functionality?

Question 5. Do you think the navigation in the application was practical and understandable to complete the task?

As it can be seen in the graphic, the task 9 (Generate route) was the less understandable one, followed by the task 8 (Generate alerts). In the other tasks almost all the users specified that the navigation was very understandable or understandable. In Figure 6, results are shown.

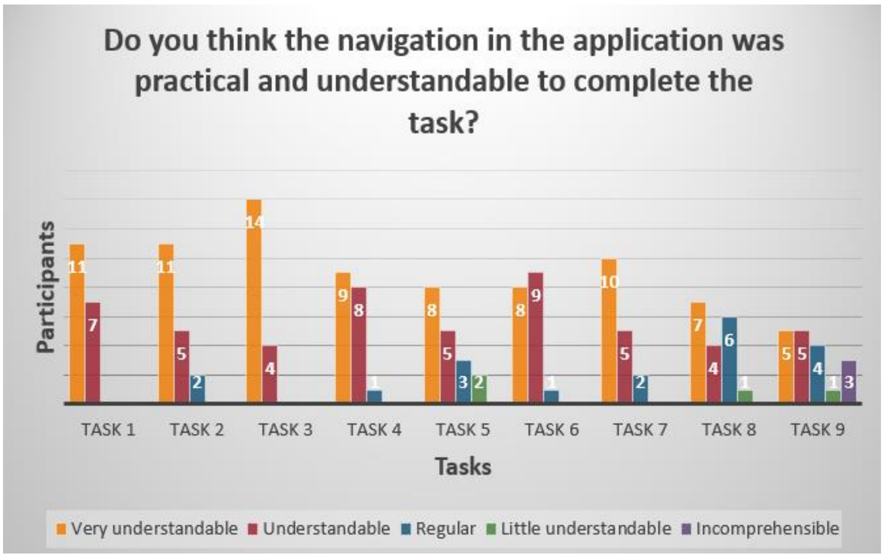

Figure 6: Results of question 5: Do you think the navigation in the application was practical and understandable to complete the task?

Usability evaluation

In the usability questionnaire the following aspects were evaluated:

- The design and colours are consistent in Green Route
- The icons and graphic elements match with the functionalities of each view
- In the sections of data capture, it is understood what information is required
- Navigation options on Green Route are simple and visible
- There are no indications or screens difficult to understand within Green Route
- The design and format of the menu is familiar and consistent in Green Route

- Green Route requires a low level of configuration
- The response times for each task or function are adequate
- I think Green Route is easy to use
- I consider that I do not need technical support to be able to use Green Route
- There is no confusion in the visualization of the contents that each screen shows
- The navigation menu is useful for locating Green Route sections
- I consider that most people would use Green Route easily
- It is possible to change between functions in an accessible way
- I do not need to learn many things before I can use Green Route

According to the results, Green Route was well evaluated by the majority of the participants. However, half of the participants do not totally agree that Green Route could be easy to use for most of the people. In Figure 7 results are shown.

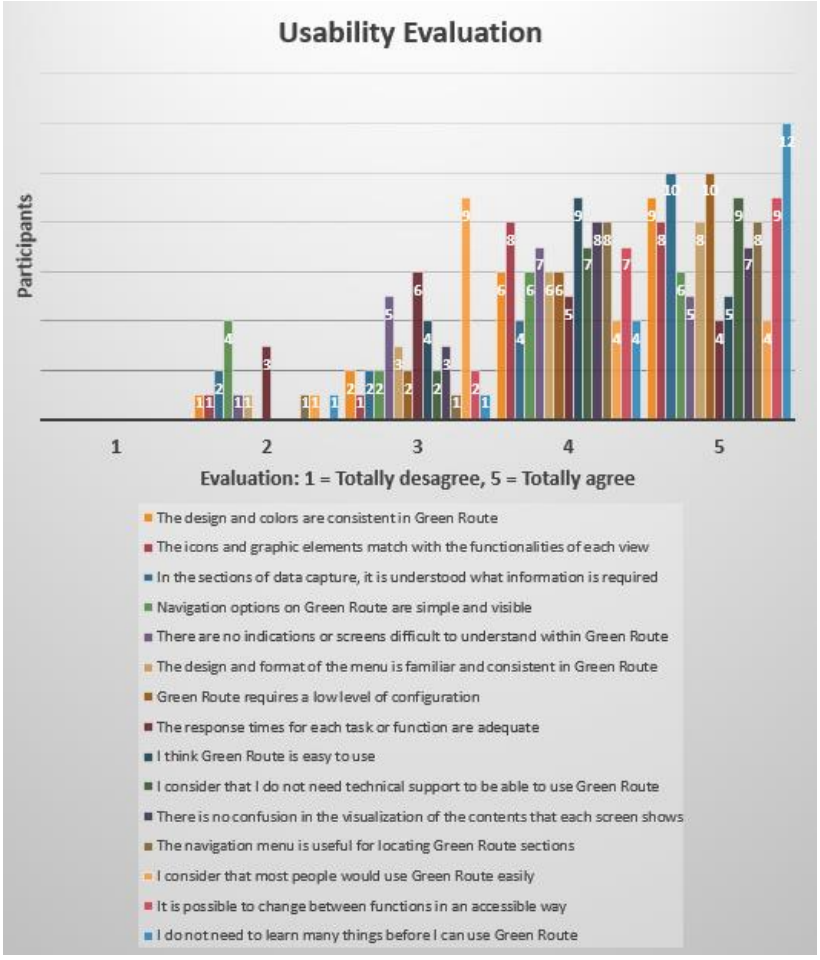

Figure 7: Results of the usability evaluation

2.5 Conclusions

According to the comments provided by the participants and the results of the after-task questionnaires, the application worked correctly during the trial and all the tasks could be executed. In general, almost all the tasks were well evaluated. However, some functions of Green Route could be improved.

- **Task 1. User registration and Login**

  The users had no problems with the registration and login. But, in a few cases the confirmation email of the account took a little while to be received by the participant.

- **Task 2. Change the password**

  The users had no problems changing the password. The only thing that can be improved is the position of the input boxes in the web version: It would be better if the input boxes appeared in one column instead of two columns. One thing that could be changed in the mobile version: the menu should hide automatically after selecting the option, instead of clicking on the menu to hide it.

- **Task 3. Password recovery**

  The users had no problems recovering the password. One thing that could be changed in the mobile version: the menu should hide automatically after selecting the option, instead of clicking on the menu to hide it.

- **Task 4. Edit user profile**

  The users had no problems editing the user profile. One thing that could be changed in the mobile version: the menu should hide automatically after selecting the option, instead of clicking on the menu to hide it.

- **Task 5. Edit health profile**

  The users had no problems editing the health profile. However, users think that it should be possible to choose the two types of profile: allergy and asthma, instead of choosing one or the other.

- **Task 6. Edit vehicle profile**

  The users had no problems editing the vehicle profile.

- **Task 7. Subscribe to groups and visualize alerts**

  The users had no problems subscribing to groups and visualizing alerts. However, it would be better if in the Show all alerts section, a notification appeared informing the user which groups he or she is subscribed to.

- **Task 8. Generate alerts**

  The users consider that there are some issues and things to improve in the Alerts functioning. It is a little bit annoying to login twice in order to generate an alert, but the integration between the Alerts application and Green Route was still in progress. It is necessary to refresh the page, after generating an alert, to visualize it in the application. Some users think that the icons of the alerts should have a name and not only an image, in order to identify the alert type faster.

- **Task 9. Generate route**

  Many users think generating a route is not an intuitive function. The way to specify a route was not easy to find for the most of them. They did not figure out that to generate a route is necessary a right click on the map to select the start and destination point, and then click on the Calculate button, they tried to write the start and destination point in the text boxes instead. Maybe the instructions to generate a route should be more visible.

2.6 Next Steps

- Minor modifications in the Green Route application in order to solve the observations obtained in the trial.

3 SMART HEALTHCARE APPLICATIONS

3.1 Introduction

This section presents three Smart Healthcare applications for mobile sensing. An application to measure the risk of fall by walking techniques, a rehabilitation monitor using wearable devices, and a robot-assisted interventions implementation.

3.2 Risk of Fall

3.2.1 Background

Population worldwide is aging as a result of improvements in health services and lower fertility rates. It is expected that by 2050, 20% of the population worldwide will be older adults[1.] Functional capacity and independence tend to diminish with age due to limited mobility, loss of strength, or other physical or mental problems. As people age, they tend to experience frailty, manifested with health and social challenges; such as decreasing vision, reduced mobility speed, loss of muscle mass, and partial hearing loss. These problems increase the demand for medication, lifestyle counselling, specialized assistance, and care attention. The increase in chronic and age-related diseases calls for a change from our current emphasis on managing disease towards an approach aimed at preventing them [9]; including tools to infer, monitor and change behaviours that might hamper wellbeing.

Advances in mobile and wearable sensing are allowing the inference of activities and behaviours associated with health by facilitating the collection of daily-life data. Several research initiatives in this area are collecting large amounts of data from studies in diverse fields of healthcare and wellbeing, raising the challenge of integrating heterogeneous datasets.

The healthcare initiative of the SmartSDK project aims to develop schemas and software infrastructure to facilitate the harmonisation, curation, and sharing of mobile sensing datasets for healthcare.

3.2.2 Objective of the application

The main purpose of the healthcare application is to expedite the harmonization and sharing of mobile sensing datasets for the healthcare domain. It focuses on mobile devices that collect data from sensors used on physical tests by following clinical protocols to assess the risk of falls.

The generated application has been designed for research purposes, thus, parameters of interest (associated to the risk of falling) are analysed *a-posteriori* and raw sensor data are kept allowing different stakeholders, such as patients and physicians to better understand how patients' activities and behaviours influence a healthier lifestyle.

3.2.3 Main functionalities

The list of functionalities for the healthcare application are presented below:

Mobile application:

- **Registration of patients:** This section allows the users to keep a record of the patients' performance.
- **Collect test data:** This section guides the user to appropriately conduct a physical test.
- **Upload data:** This section enables the user to upload data to FIWARE servers for further

[1] Organization WH. Aging. 2011

analysis.

Dashboard:

- **Search of data:** This section facilitates the query of the patient's performed test.
- **Data visualization:** It allows the user to display the results of different tests and assess the performance of a patient.

3.2.4 User Manuals

User manuals have been created in two languages, English and Spanish:

- Documentation in English: http://ma-test-fiware.readthedocs.io/en/latest/
- Documentation in Spanish: http://ma-test-fiware.readthedocs.io/es/latest/
- Docker images: https://hub.docker.com/r/smartsdk/mat-dashboard/

3.2.5 Study Design

The smartphone was placed in the participant's lower back as indicated in the user's manual (Figure 8).

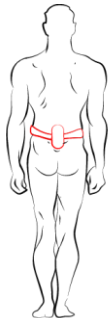

Figure 8: Device were placed in the lower back

Data were collected while the participants performed three different physical tests, as described below:

The Timed Up and Go (TUG) Test:

- The participant stands up from a chair.
- The participant walks along a 6-meters marked line on a regular pace.
- The participant walks back to the chair at a regular pace.
- The participant sits down.
- The evaluator stops the application after the participant has sat down.

The 30-Second Chair Stand Test:

- The participant seats in the middle of a chair with hands on the opposite shoulder crossed by the wrists, the feet are to be resting on the ground and the participant's back is to be straight.
- The participant is incorporated into a complete standing position and then returns to sit.
- The participant must repeat step 3 for 30 seconds as fast as possible.
- Data collection stops after 30 seconds.

The 4-Stage Balance Test:

- There are four progressively more complex positions. Participants should not use any help device (walking stick) and should keep their eyes open.

- The evaluator should stand next to the participant, hold his arm and provide help to assume the correct position of the feet. When the participant is stable, the evaluator must release him / her, but stay close to hold them it in case they lose their balance.
- The participant maintains the position for 10 seconds. The four positions to take into account for the balance test are:
    - **Feet together:** Feet side to side
    - **Semi-tandem:** The instep of one foot at the height of the big toe of the other foot.
    - **Tandem:** One foot forward of the other, the heel touching the tip of the foot.
    - **Lame paw:** Standing on one foot

Note that the subjects performed the physical tests in a controlled area in space (i.e., areas with dimensions greater than 10 x 5 meters free of obstacles) where the technical support necessary to develop the tests was available.

3.2.6 Parameters of interest

The risk of falling is based on the calculation of parameter of interest derived from the previous mechanisms. Thus, in this trial, data are calculated after retrieving the input collected during the physical tests.

Parameters obtained in the TUG test:

- Speed of travel.
- Distance between steps.
- Time between steps.

Parameters obtained in the 30-Second Chair Stand test:

- Number of repetitions.
- Time between repetitions.

Parameters obtained in the 4-Stage Balance test:

- Time in position.
- Rolling index.

3.2.7 Methodology

The study was carried out in the facilities of the research centre CICESE, enabling 3 common areas: (1) waiting area in which entertainment material is provided to participants, (2) obstacle free test area with a minimum dimension of 10 x 5 meters, and (3) a recovery area.

The execution of the physical tests lasted approximately 10 minutes, however, the approximate time that the participants were involved in the collection of data was approximately 40 minutes, as illustrated in Figure 9.

SCHEDULE OF ACTIVITIES	Duration in minutes			
	10	10	10	10
ACTIVIDAD				
Training (pre-tests)				
Response to questions and comments by the participant				
Reading and signing of consent letter				
Rest and recreation (eg, reading magazines)				
Execution of physical tests				
Rest				

Figure 9: Schedule of the execution of the physical tests.

3.2.8 Participants and inclusion criteria

The target population consisted of healthy adults of any gender and with availability of time. Testing was planned primarily with CICESE staff and students interested in participating.

Participants had to meet the following inclusion criteria:

- Do not depend on walking equipment (i.e. walker, walking stick).
- Do not have chronic diseases.
- Not having suffered a fall in the older adult stage (i.e., after age 60).

3.2.9 Results

A trial was conducted from August 28th to 31st, 2017 involving the participation of 20 adults (15 men and 5 women. Mean: 27.25 years, Standard Deviation: 4.89 years).

The number of events automatically identified were compared to the events visually quantified using video recording (as a ground-truth element) for each performed test. Accuracy on the number of events with a precision of 87%.

The main purpose of this initial project was to showcase a mobile device's data model. This project demonstrates its adoption in health care application using mobile devices (i.e., smartphone).

3.3 Rehabilitation Monitor

3.3.1 Background

Stroke survivors often have motor impairment among the sequelae. Neurorehabilitation aims at returning the patients their lost functionality so that they can go on with their life independent from other people. Traditional neurorehabilitation therapies have been majorly administered at specialized hospital wards dedicated to physical and occupational therapies in the modality of outpatients. Monitoring the patient while at home has been hindered by a number of issues (cost, lack of pervasive sensing platform, etc.) until recently.

Virtual rehabilitation proposed a fresh paradigm where motor training occurs on virtual environments. Its effectiveness and impact on stroke patients have been below the initial expectations because our generalized ignorance about the neurorehabilitation process itself, as well as because we do not understand the conditions on which learning transfer occurs from the virtual to the real environment. A critical aspect of such transfer is timing, and in the case of neurorehabilitation, when should the therapy be administered. Previously, our group has investigated the impact of a virtual rehabilitation platform in chronic patients. Now we are researching the impact on earlier stages that is the acute and subacute stages, when the natural plasticity has been shown to exhibit a peak of activity. The more recent scientific evidence questions the general perception that a very early intervention may be counterproductive.

3.3.2 Objective of the application

The rehabilitation monitor SmartSDK Health Rehabilitation App is conceived to estimate the newly proposed Index of limb usage balance – ILUB. The ILUB is an index to estimate the preference in use of either upper limb in everyday life. It is calculated from accelerometer data from two smartwatches (one on each wrist), synchronised with the cloud through a smart phone.

3.3.3 Main functionalities

For this stage, we focused on the behaviour (sleep) detection. Thus, we developed the following components to implement the proposed scenario.

- **Gathering Accelerometer Data**. We developed an application to gather data from the smart-watches sensors and in particular from the accelerometers. This application synchronizes data from 2 smartwatches (one per arm) with an Android application in a cell-phone to send data to the Context-Broker.
- **Cloud Communication**. We developed an Android application to send information to the Context-broker.
- **ILUB estimation**: We developed an off-line operationalization of the ILUB, that upon manual downloading of collected data from the cloud, provides an estimation of limb usage with respect to a healthy population (based on experimental evidence).

3.3.4 User Manuals

Technical and user guides have been prepared, which can be found at https://smartsdk-healthapp-rehabilitation.readthedocs.io/en/latest/.

3.3.5 Results of the trial

Thus far, data from 20 healthy participants and preliminary 2 patients (this latter as part of a related clinical trial being conducted at Instituto Nacional de Neurología y Neurocirugía, Mexico City), have been collected. For each participant, data were collected for the experimentally agreed period lasting a fixed number of sessions, but which may be associated to a variable number of days (e.g. for patients, the length of the in-ward treatment may have differences in schedule). Collected data are being analysed with preliminary results summarized below.

A total of 219 files were collected. Available data files were filtered to remove empty files (42 files), test files (7 files) and files for which we were unable to establish origin, e.g. subject and session pair (5 files). The remaining were manually tagged with subject and session ID since the current version of the software only saves the date and time for blinding, ensuring data privacy. Then, the 165 surviving data files were split in terms of sample origin (right or left hand), resampled to even-spaced sampling rate, zero-padded and low pass filtered with a moving average filter. Then, analysis first calculated the magnitude of the accelerometry vector, estimated the area under the curve (using the trapezoidal approximation) and calculated the laterality index (LI) for each data file. Finally, the ILUB was established for each case.

Resulting data was organised into a small database with the following columns:

- Subject ID
- Session ID

- Handedness score
- ILUB
- LI
- AUC_{acc} for right hand
- AUC_{acc} for left hand

Please note that there may be several observations i.e. several data files, for each pair <Subject ID, Session ID>.

From this database, we have established the initial relation between the LI and ILUB with respect to the handedness score.

Our preliminary findings suggest positive trends in LI (see Figure 10) and ILUB with increasing handedness score for the healthy population as hypothesized, but these have not reached significance with the current sample size. Positive relation hypothesized and found between the handedness score as measured with the Edinburgh inventory and population LI as established from accelerometer data from the smartwatches for healthy subjects. Only averaged LI for each handedness score are shown.

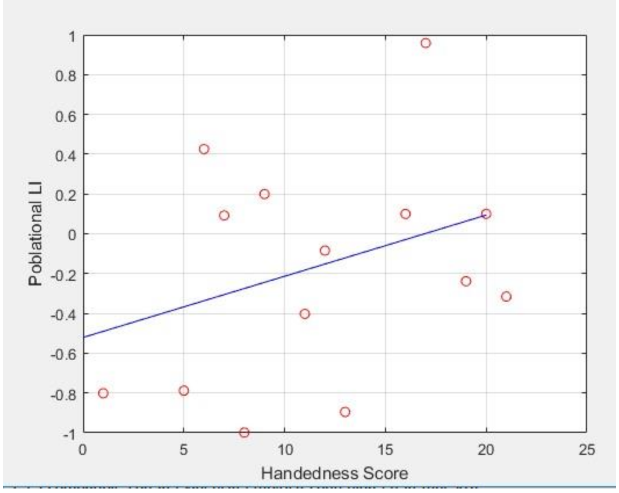

Figure 10: Positive trends in LI

3.3.6 Study design

For this pilot, we worked on healthy participants, since the goal is to evaluate the application for monitoring and not specifically validate a new therapy for stroke rehabilitation. Being a pilot, we did not carry out a power analysis, and instead, the sample size was constrained by the recruitment period. It was intended to enrol at least 6 to 8 participants (plus a 15% drop off rate), but we surpassed that number. This is even considering that we were limited by our infrastructure (we only have 5 smartwatches and 3 smartphones to perform the study).

The study has been designed as a cross-sectional study (1 session per experimental unit), where the session involves a week of data collection through the application.

Following the identification of potential candidates within INAOE's community, the candidates were contacted in person to be enrolled as potential volunteers. The volunteers were explained the goal of the research study with the help of an information sheet describing the particulars of the study as well as the rights of the participant to withdraw from the study at any time without providing any further explanation and its unconditional right over his/her data at all times. They were also informed in the sheet about the nature of the data that will be collected and how it will be used for scientific purposes, including potential publication of blinded data. Having read the information sheet, the volunteers were allowed to make as many questions as they may please about the study and the recruiter would make the best of her efforts to answer to those. There was no limit on the time to reach a decision to participate or not in the study.

If the volunteer decided to proceed and accepted participating in the study, he was invited to sign an informed consent form. Upon signing, the participant was assigned an alphanumeric code that is registered in the consent form and as from that moment onwards he will only be referred to in all documentation throughout the study by this alphanumeric code. Only the person in charge of recruiting and Prof Sucar and Dr. Orihuela have access to the consent forms and hence are the only persons capable of identifying the subjects. Regardless of the decision and signature to the consent form, the participant maintains at all times the right to abandon the study and to eliminate his data from further use and analysis, without this affecting subsequent decisions any of his rights or potentially altering his participation in future studies.

The initial evaluation has been carried out at Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE) and in this evaluation the inclusion criteria were checked. Demographical data was collected at this point in time including full name -in the consent form only-, age, gender, occupation, civil status, ability to follow the instructions of the protocol, address, and check of medical conditions affecting his participation. All these data have been and will be treated confidentially.

3.3.7 Parameters of interest

The principal endpoint is the ILUB defined as the ratio of the limb laterality index for the patient and the whole population adjusted by handedness. Secondary endpoints also included; raw traces of the accelerometer from both left and right smartwatch, area under the curve of the traces, usability questionnaire, and demographical data.

3.3.8 Methodology

The experimental protocol was as follows:

- Monday (afternoon): Informed consent was acquired from the participant, who was then provided with the platform. Demographical data (age, gender, occupation, etc.) was collected and the Spanish version of the Edinburgh handedness inventory applied.
- Tuesday to Thursday (whole day): The participant made continuous use of the platform and software.
- Friday (midday): The participant would return the platform (smartwatches and smartphone and chargers), his/her data in the cloud would be consolidated and a bespoken user experience questionnaire applied.

Although the watches may acquire data at 50Hz, neurorehabilitation processes last for years and variations in motor dexterity are extremely slow. In this sense, a high sampling rate has been considered unnecessary and consequently sampling rate was low pass filtered.

Descriptive and inferential statistical analysis is currently undergoing. See preliminary results in Section 3.3.5.

3.3.9 Participants and inclusion criteria

Individuals from the INAOE community were recruited to participate in this study including students and faculty members. Inclusion criteria:

- Healthy adults (>18 years old).
- Capacity to understand and follow instructions.
- Absence of clinical history of known conditions that may interfere with the protocol e.g. motor impairments, neuropsychological conditions, etc.

NOTE: We have not carried out a neuropsychological evaluation of the participants. The volunteers were openly asked about any medical conditions that they might think may interfere with the study, and their word was taken at face value.

Exclusion criteria:

- Inability to use digital platforms e.g. digital illiteracy.
- Inability (economical, working, or of any other nature) to get to INAOE in the opening and closing dates for the week session.

Elimination criteria:

- No adherence to protocol. At least data from 3 days were required, of which at least 2 must have been usable for analysis. Usable here refers to at least 4 hours' worth of data in total during the same day.

3.3.10 Results

A pilot study is ongoing that intends to act as a proof of concept regarding the possibility to measure patient limb usage at home with this kind of technology. During the pilot, the feasibility of the application will be tested (for instance regarding the battery consumption or the detection of critical bugs) in order to establish limitations and/or improvements for a trial on real patients. A number of bugs and limitations of the application have been detected and addressed resulting in an improved version of the application.

Regarding the collected data, we found a non-significant positive trend between healthy population handedness score and laterality index. This, relation is used to normalise the individuals LI to establish the ILUB. Our analysis of data is still ongoing at the time of writing.

3.4 Adaptive Conversational Robot using Biosignals

3.4.1 Background

Robot Therapy (RT) has emerged as a non-pharmacological intervention to promote social contact as well as cognitive and physical stimulation. These interventions use robots to simulate human and animal contact [10]. RT is mainly conducted with Social Assistive Robots (SAR), these are robots that provide assistance through social rather than physical interaction. A SAR is a system that employs hands-off interaction strategies, such as the use of speech, facial expressions, and communicative gestures, to provide assistance in accordance with a particular healthcare context [11].

In the domain of Human-Robot Interaction (HRI), the development of adaptive robot interfaces is one of the most significant challenges to provide a realistic interaction between human and robots. The use of wearable sensors and advances in pattern recognition algorithms is enabling the inference of increasingly complex human activities and behaviours. These sensors (e.g., cameras, microphones, accelerometer, gyroscope, and heart-rate) have been used to gather first-hand data to infer a particular behaviour. This can be used to adapt systems based on activity and behaviours detected. In the health-care context, biosignals obtained from wearable sensors have been used to detect anxiety, seizures, agitation and aggression.

3.4.2 Objective of the application

As one of the aims for healthcare initiative of the SmartSDK project, we propose the use of wearable sensors for biosignals to detect activity and behaviour that can be used as input to adapt the behaviour of a SAR used to conduct therapeutic interventions. We used the Robot Eva as a SAR for this project. Eva is an anthropomorphic conversational robot capable of understanding natural language and interacting via voice.

Particularly, we focus on detecting sleep states. Thus, it is possible to detect abnormal behaviours during the night and then send a signal to the robot Eva to enact interventions to deal with this behaviour using methods to induce sleep or notify caregivers. Below we describe an application scenario obtained from a contextual study where caregivers and geriatricians participated.

Application Scenario. *Bob experiences sleep disorders. A caregiver often stays for a few minutes talking to Bob until he falls asleep. He has decided to install Eva in Bob's room so that the robot will do the talking. Eva plays some relaxing music and talks to Bob, while monitoring his heart rate from the sensor in Bob's smartwatch. This allows Eva to monitor when Bob relaxes and adapts what it says and the volume. When there is strong evidence that Bob has fallen asleep, Eva gradually stops the conversation and music. If Bob wakes up and becomes anxious, Eva will be aware of this through the monitoring of his heart rate and will attempt to relax him so that he gets back to sleep or will notify the caregiver if Bob attempts to get off the bed.*

3.4.3 Main functionalities

For this stage, we focused on the behaviour (sleep) detection. Thus, we developed the following components to implement the proposed scenario.

- **Gathering Heart-Rate Data.** We developed an Android-Wear application to gather data from the heart-rate sensor. This application must be synchronized with an Android application in a cell phone to send data to the Context-Broker.
- **Cloud Communication.** We developed an Android application to send information to the Context-broker. This application used HTTP methods to share the data gathered from a smartwatch.
- **Sleep detection.** We developed a back-end application using NodeJS. This application is subscribed to the Context-Broker to gather information automatically. We implemented a moving-average based algorithm to detect sleep states. Besides, we developed a front-end application to monitor the gathered data in real time.

3.4.4 User Manuals

At this stage, we do not release a production application. Thus, user documentation related to the application is not available yet.

3.4.5 Results of the trial

The components were separately validated. Once the components were integrated as a system, we tested its functionality. After some iterations, the application was ready to be used in a preliminary study.

3.4.6 Study design

We conducted a preliminary study to analyse the feasibility of the application scenario described above. This study focused on analysis of the heart rate signal to determine possible states during the night such as sleep and some undesirable activities (e.g., waking up, getting up from bed). If it is possible to infer these activities, this can be an input to adapt Eva's behaviour by helping people relax and get back to sleep.

3.4.7 Parameter of interest

The global parameter of interest for our application is the abnormal behaviours during sleep. Thus, we consider a set of parameters as a component of the primary parameter.

- **Sleep time.** An approximation (in seconds) of the sleep-time of the users.

- **Sleep lapse detection.** Real-time Detection of lapses when the users are sleeping.
- **Wake/Get-up detection.** Real-time detection of activity related to wake/get-up of users.

3.4.8 Methodology

We divided the test into 4 stages to address the objective (see Figure 11). At this moment, we concluded 3 stages, all of them related for the sleep states detection. Iterating over of each stage, we developed an application to detect sleep state. Later, we conducted a preliminary study to assess the feasibility of the application.

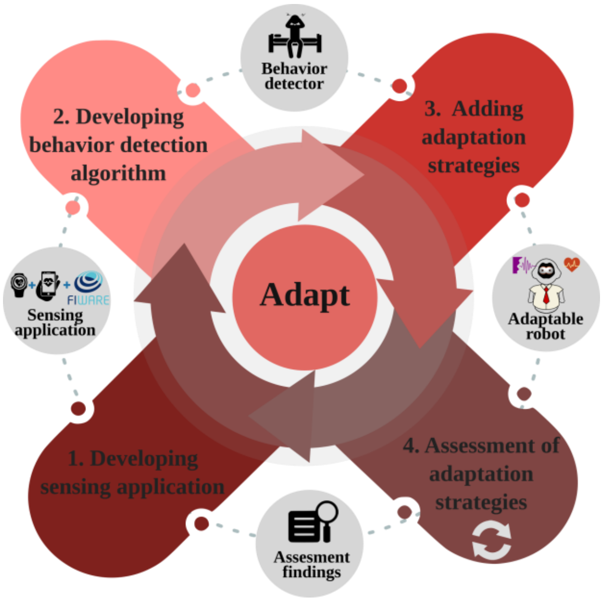

Figure 11: Methodology to develop and test a wearable application to detect sleep disorder behaviour.

3.4.9 Participants and inclusion criteria

Two individuals (part of our staff) participated in the study. For 3 nights, participants used a smartwatch running the application to monitor their heart rate. Furthermore, participant's auto reported their activities. Thus, we gathered information about which activities were related to HR signal segments.

3.4.10 Results

The figure below (Figure 12) shows a graph of Heart-Rate (HR) signal from participant 2. The first insight of a visual analysis was that the HR signal decreases during sleep lapses and an atypical activity increases HR. Throughout the sleep period, the signal increases two times, in both of these occasions the participant got up and went to the bathroom. We developed a moving-average based algorithm to detect when the person wakes up by defining a threshold of average HR, a window size (seconds), and a number of windows to sample.

The green zone of the graph represents sleep periods obtained from our algorithm. As it can be seen in the figure, go-to-the-bathroom events were excluded from the green zone; it means that the algorithm detected these atypical events. This preliminary result indicates the feasibility to detect atypical events during the night. Thus, we could use this detection as input to adapt the behaviour of the robot Eva as was described in the application scenario. In Figure 12, the HR signal obtained from a participant 2 is shown. The proposed algorithm detects the sleeping states (green zones) and those where the participant was doing a different activity (cooking, eating, and walking).

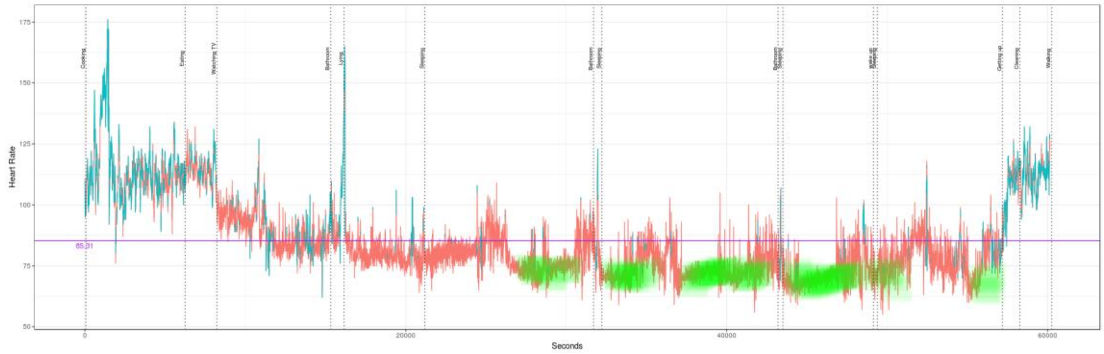

Figure 12: HR signal obtained from a participant 2.

4 SMART SECURITY APPLICATION

4.1 Introduction

This section presents the Smart Security application for intelligent video surveillance. This application is developed by INAOE, CENIDET and ITESM partners as part of the SmartSDK project. The Smart Security Application is based on two modules, a web module (ViVA) and a mobile module (Driving App). Figure 13 shows a view of these modules.

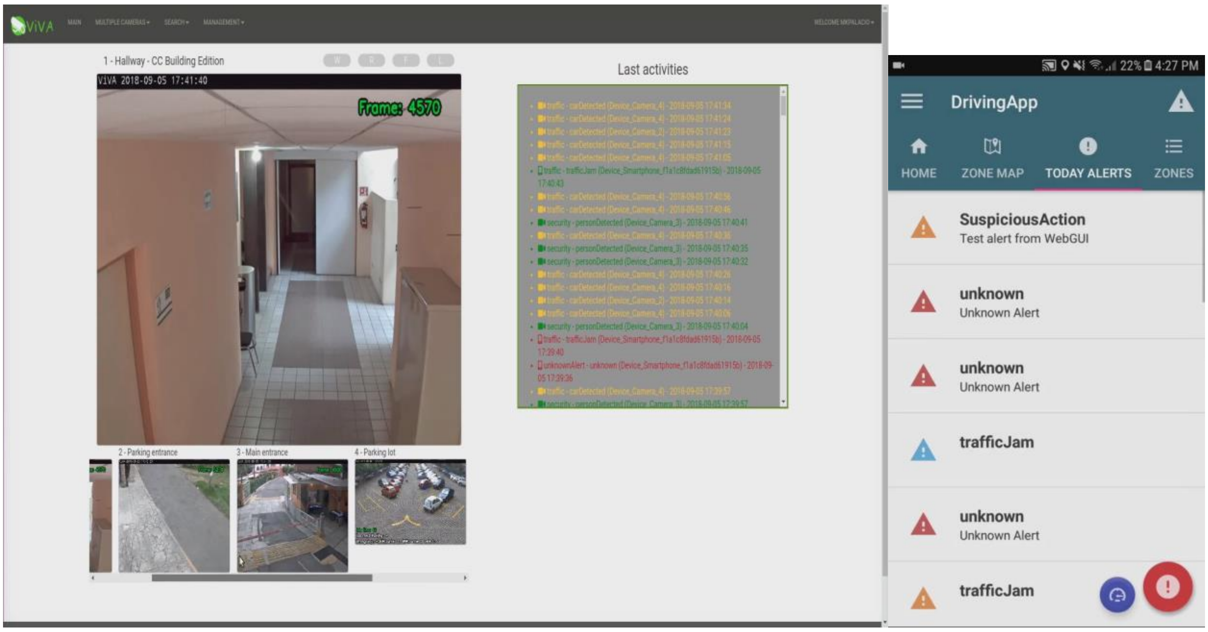

Figure 13: The Smart Security Application: Views of the web and mobile modules.

4.1.1 Background

Ensuring society's security and welfare is one of the main concerns of many governments. In an attempt to achieve these goals, global leaders along the private sector are reaching out to the state-of-the-art technologies trying to find a solution for their security problems. To be more accurate, in the fields of machine learning and data analysis, mainly because these disciplines are applied to huge amounts of data, which eases their interpretation and allows an expert to make a decision based on the summarized version of the original information.

A common way to improve security is with the use of video surveillance systems; however, traditional video surveillance systems manage a huge amount of information obtained from cameras. In most of the cases, the information is retrieved after a security event has happened. On the other hand, the security team in charge that use this type of systems has to watch all the screens for a long period of time trying not to lose details. Thus, a system that can analyse the information produced by the video cameras in order to reduce the load for the security guards is required.

The Smart Security Application is an automatic video surveillance system that aims to assist to the security team of an institution or company. The Smart Security Application is based on both video cameras and smartphones sensors, this means, it is based on two modules, a web module and a mobile module. The web module consists of an automated video surveillance approach that integrates the cloud-computing schema, computer vision algorithms and data management features, as a long-term solution. The mobile module is a mobile application to monitor the driving of the vehicles within the facilities of the institution, through the automatic detection of risk events in the incorrect driving of the vehicle. The event detection will allow notifications to the users about the occurred events including their location through alerts.

4.1.2 Objective of the application

The Smart Security Application has the main objective of providing automatic assistance to every person in charge of the security where a video camera network is available. Thus, a person in charge of security (a guard), can be notified by the system at the moment when the event is happening. So, the guard can execute the security protocol in order to prevent a damage.

The implemented application has the following capabilities:

- Provide real-time summarized information for the user, indicating relevant events that occur in the area under surveillance.
- Store the relevant events for future access, facilitating an easy and efficient search for the user.

These capabilities include analysis of video from several cameras, including recording when movement is detected, real time detection of people and vehicles from a set of video cameras, generating notifications related to certain events that occur within the monitored area and a friendly graphical user interface (GUI) that eases the management of data generated by the system and its interaction with the users. Additionally, a mobile application is also available for both alert management and automatic detection of events based on smartphone sensors that complement the functionalities of the Smart Security Application.

4.1.3 Main functionalities

The main functionalities of the Smart Security Application can be summarized as following:

Web Module:

- **Live video visualization:** The web GUI provides the user two ways of displaying real-time video: By a specific camera (in order to see more details) or by a grid of all the cameras registered in the system.
- **Markers and Settings:** When an event is detected, it is highlighted by boxes or text on the video streaming. For instance, when a person is detected, the system displays a rectangle enclosing the person. The figure shape and colour can be customized by the user.
- **Video Storage:** The system provides the functionality of recording videos by automatic movement detection. Thus, the system saves short videos only.
- **Searching and Visualization of stored video:** The system is able to play videos previously stored. In order to ease the access to a determined video, the GUI provides input controls that enable searching by certain criteria such as camera ID and date/time the video was stored.
- **User Management:** The system considers three types of users: administrator, security and mobile. In order to guarantee privacy of the information, a registration process is required; thus, only registered users have access to the system. Every registration request must be accepted by a user with administrator privileges. When the request is accepted, also the role of the new user is provided.
- **Alerts Visualization:** Every automatic event detected by both the video processing module and the mobile module are notified to the user by showing a message in the "Last Activities" box in the Main view of the web GUI. The message shows a colour and an icon that represents the priority and the source of the alert. As the alert is sent to the Context Broker, also the mobile users are notified.
- **Zone, Parking and Roads Management:** The system provides several views to the user in order to manage the general zones, parking and roads that are in the monitored area.
- **Mobile Alerts Search.** The system includes a view where the user can search the current or previous alerts generated by mobile users.

- **Map visualization:** A map view is integrated to the system in order to show a general overview of the complete camera network. Left-click on the pin shows a small streaming view. Right-click shows information about the alerts notified. Also, the colour of the pin shows the priority of the last events.

Mobile Module:

- **User registration and authentication:** The mobile app enables the registration of new mobile users and also provides access to users with an account previously registered through web module. This user's registration and authentication is required to guarantee privacy of the user's information and provide access to the functionalities that incorporates the mobile app.
- **User Location Detection**: The mobile app displays the location of the user, showing the name and address of the area where this is located, and also the delimitation of this area in a map, making focus on the user's location inside of the area.
- **Alerts Visualization**: The mobile app has the functionality of showing the alerts received in a list classifying them by alerts generated during the day (Figure 13), and latest ten alerts (the recent alerts). Each one of these alerts can be seen by the user in the map, where the alert location and its associated information are shown.
- **Manual Generation of Alerts:** The mobile app allows the generation of manual alerts related to traffic and security events, these alerts can be sent by the mobile users at the moment they observe an event of these categories.
- **Alerts Notifications:** In addition to showing the alerts list to the user, the mobile app has the functionality of receiving notifications. These notifications can come from alerts generated by automatic detection of events or manual alerts generated by the other users.
- **Map Visualization of Areas and Roads:** The mobile app shows to the user the institution areas marked on a map, these areas are the principal zone of the institution and the parking inside, which appear delimited in the map views. The maps also present the lines (in highlighted form) that identify the roads that are within the institution parking or other areas.
- **Driving View for driver users:** This mobile app functionality aims to provide a "driving mode" for the mobile users driving within the institution; for this, the mobile app includes a driving view where the vehicle's speed is shown in addition to the events that are detected when the user is driving dangerously or illegally.

Computer Vision Algorithms:

- **Left Object Detection:** A basic vision algorithm has been implemented in order to detect when an object is left behind in some monitored area.
- **Face Recognition:** The system provides a basic search functionality based on face identification. The user provides one or more face images (of the same person), and the system searches the person in a group of previously saved videos.
- **Walking, Running and Fighting Recognition:** An algorithm based on optical flow technique was implemented in order to detect activities like walking, running and fighting.
- **Wrong Way Driving Detection:** For parking environments, an algorithm able to detect when a car is driven in a wrong direction has been implemented. Information like directions of the parking are required as input of the algorithm.
- **Movement Detection:** The system has the functionality to detect movement within a monitored area. Based on this functionality, the system is able to storage video only when movement is detected.
- **People Detection:** The system has the functionality to detect people within a monitored area, whether it is an indoor or outdoor scene.

- **Vehicles Detection:** The system has the functionality to detect a variety of vehicles, such as sedans, trucks and buses, for instance.

Based on smartphone sensor Algorithms:

- **Unauthorized Speed Driving Detection:** The system, through the mobile app, has the functionality to detect vehicles driving at an unauthorized speed, over the allowed limit or below the limit specified in the road where the user is driving.
- **Wrong Way Driving Detection:** The system, through the mobile app, has the functionality of detecting if a vehicle is driving in the opposite direction according to the established direction of the way.
- **Sudden Stops Driving Detection:** The system, through the mobile app, has the functionality of detecting the variations in the vehicle speed, it means when the vehicle increases or decreases the speed and after a while this stops abruptly.

It is important to mention that not all the video-processing algorithms are running in the final integrated version of the system. This is because of a computation limitation. In a future, we will explore the use of CUDA [8] in order to optimize the system.

4.2 User Manuals

User manuals have been created in two languages English and Spanish.

The user manuals for the video surveillance web module are in the following links:

- Documentation in English: http://video-surveillance-application.readthedocs.io/en/latest/.
- Documentation in Spanish: http://video-surveillance-application-es.readthedocs.io/es/latest/

The user manuals for the mobile module DrivingApp are in the following links:

- Documentation in English: https://drivingapp.readthedocs.io/en/latest/
- Documentation in Spanish: http://video-surveillance-application-es.readthedocs.io/es/latest/

4.3 User trials

To develop and evaluate the smart security app, we have implemented a realistic video surveillance prototype that includes five cameras, three outdoor and two indoor, at INAOE and ITESM campuses.

The trial was performed at ITESM Campus Estado de México, which incorporates more dynamic scenarios and security guards, which are of course the main users of the system. The study was proposed by Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE), Centro Nacional de Investigación y Desarrollo Tecnológico (CENIDET) and Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM) as members of the SmartSDK project consortium.

The study aimed to evaluate the usability of the security application regarding the monitoring of environments through video cameras and smartphones. The study used a web user interface (PC with a browser) and a mobile user interface (a smartphone with the app installed). The former produced visual information regarding video camera streaming. The latter was able to produce information based on the alarms of important events that should be monitored by the guard.

The usability test was conducted by means of eight tasks. The security guard used the mobile and the video surveillance prototype to solve each task. After the tasks were completed, the user answered a questionnaire based on how much easier was to solve the tasks with the system. At the end, the user answered a final questionnaire that included open questions to capture the improvements that could be done on the system.

Because of some management issues with the security team at ITESM, we applied the study to the security manager only. Despite this situation, we collected valuable information because of the wide experience and knowledge of the security manager in the domain. Also, we had feedback from a usability expert who helped us to design the test.

During the execution, the testing team took notes of the visual and oral evaluation. Some of the main comments and suggestions were:

- The tasks were quite easy to execute.
- The functionalities included in the system will definitively facilitate the daily work of the security guards.
- The functionalities of the system are well integrated.
- Screens are needed to visualize all the cameras in the campus as they are in other systems.
- The events reported in the main window should include more information so users can appreciate the system's intelligence.

The results were centred on the search option to facilitate the retrieval of past events using different options and the visualization of more than 20 cameras. In general, users want to have the functionalities provided in traditional systems, although they appreciate the novel features in ViVA.

Regarding the development of the system, it was a great challenge to use the generic enabler Kurento, due to the confusing documentation and little support of the enabler developers. On the other hand, two important issues were identified that can decrease the performance of this type of applications: the bandwidth of the network and the processing power required for the execution of complex algorithms capable of responding in real time. As future work, we will develop a distributed and hierarchical approach for video processing, and we will incorporate CUDA to increase the performance.

4.3.1 DrivingApp

Additional usability tests of the mobile application DrivingApp were carried out in CENIDET, with a group of 11 participants. The usability tests were done through two types of questionnaires: a *task evaluation questionnaire* and a *general usability questionnaire*.

The *task evaluation questionnaire* was focused on measuring the usability of the application in the execution of tasks. This questionnaire was given to the participants at the end of each of the tasks indicated in the guide that was provided to each participant.

The tasks evaluated in this test were the following:

- **Task 1**: Download and installation of the mobile application.
- **Task 2:** Registration of user account and login.
- **Task 3:** Identification of the user's location.
- **Task 4:** Generation of manual alerts of traffic and security.
- **Task 5:** Reception of alerts notifications and their visualization on the map.
- **Task 6:** Visualization of the alerts list and their location on the map.

After completing each of the tasks, the participant evaluated with 5 usability questions each task. The aspects evaluated by question were the following:

- **1)** Level of ease to complete the task.
- **2)** Ease of understanding to complete the task.
- **3)** Level of previous learning to perform the task.
- **4)** Quickness identification of the application elements.
- **5)** Level of comprehension of the application response.

The results of the *task evaluation questionnaire* show that a high number of participants completed the tasks with ease and understood the activities they had to carry out to complete each task. In addition, in the execution of the tasks, the participants required little assistance to manipulate the functionalities of the application. These results of the evaluation of tasks were aligned with the results obtained in the *general usability questionnaire* of the application.

The *general usability questionnaire* aimed to measure the degree of satisfaction that participants had with the application. This questionnaire was composed of a list of 15 affirmations of the application, to which each participant had to answer whether he/she agreed or disagreed, using the Likert scale with the values 1 to 5, considering value 1 as totally disagree and 5 as totally agree.

The affirmations of the general usability questionnaire were the following:

- The design and colours are consistent in the application.
- The icons and graph elements are aligned with the functionalities of each view.
- In the sections of data capture, it is understood what information is required and is easy to remember.
- There are no indications or screens difficult to understand in the application.
- The navigation menu is useful to locate the sections of the application.
- The design of the menu is familiar and consistent throughout the application.
- The options of navigation between the views of the application are simple and visible.
- The application has an accessible navigation and is easy to understand.
- The navigation of the application is familiar to the navigation of other similar applications.
- The application requires low level of configuration.
- It is possible to switch between functions of the application in an accessible way.
- The functionalities of the application are easy to learn and use.
- The response times of the application is adequate.
- There is no confusion in the visualization of the content of each view.
- Each interface of the application is distinguished from the others.

There was a total of 165 answers per indicator. Answers in the range 1 (Totally disagree) to 3 (Neutral) were considered as “Unsatisfied”, whereas answers 4 (Agree) and 5 (Totally agree) were classified as “Satisfied”.

According to the numbers of answers, the results of this questionnaire shown that 79% of the participants of the tests are highly satisfied with the application; qualifying it as usable and accessible, in aspects of design, functionality, content and navigation. The 21% of the remaining users express do not agree with some icons and graphics elements in the views, design and color, and also in the navigation options of some views in the application. Figure 14 shows these results represented in a graphic or percentage.

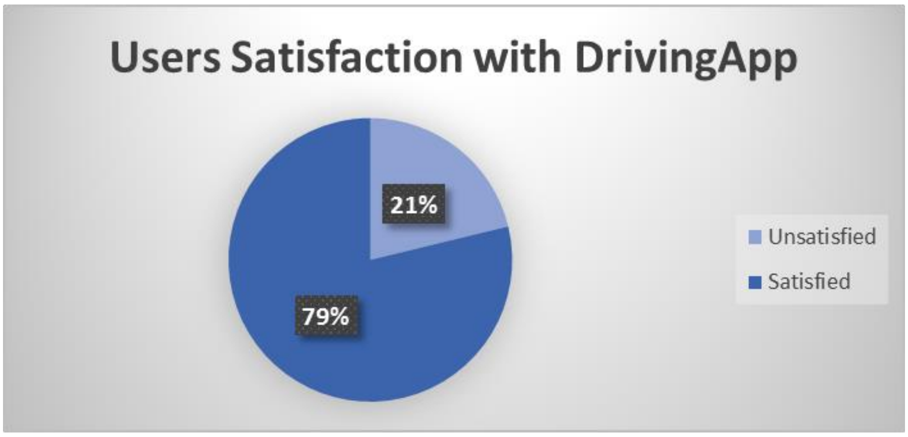

Figure 14: Percentage of satisfaction of the users with the application DrivingApp.

In future usability evaluations, the goal is to improve those aspects of the application with which 21% of the remaining users do not agree, and which cause dissatisfaction with the manipulation of the application. Future action plans could include optimization of the performance of the application in the execution and response of each task.

4.4 Next steps

- **Dockerization:** A basic version of the system is being prepared with Docker.
- **Documentation:** We will update the documentation of both web and mobile modules of the system.
- **Parallelization:** Distributed approach for video processing and introduction of CUDA.
- **DrivingApp:** Improvements on graphic elements and performance

5 CONCLUSION

This document presents the status of the Smart City, Smart HealthCare and Smart Security applications. Besides, for each application the trials and their results are presented. Furthermore, links to the reference user manual with the main functionalities of the software components were given.

Green Route application, developed in the Smart City scenario, allows to visualize in a map the current conditions of pollution, weather, traffic and allergenic elements in Mexico City, and also use this information to determine the best route to reach a destination from the list of optional (bus, car, walking routes). Complementing Green Route, the Alerts Application is able to provide users with the generation of geolocated alerts related to health, security, environment, traffic, and weather situations. The trials brought positive feedback from the testing users and a clear indication on which points needed further improvement, such as making the specification of the route more intuitive.

Three Smart Healthcare applications we presented, showcasing the use of sensor data collected from wearable and mobile devices to be used as part of healthcare technology solutions. Firstly, there was MA-Test, consisting of a mobile app and a dashboard web interface to retrieve and showcase the risk of fall of a person while walking. Secondly, a wearable application to detect sleep states was developed and tested. The app gathers information from a user using the HR sensor of a smartwatch, and in a real-time sends data to the FIWARE-based back-end application to process the information from more powerful stations. The third presented an ongoing study based on adaptive conversational robots. The experience of the trials revealed the benefits of FIWARE as a post-processing platform for gathered data from sensors. All these applications contributed new DataModels defined for the applications.

The Smart Security application is an automatic video surveillance system based on the FIWARE framework designed to assist the users of an institution in the detection of risk events. These are detected based on the information provided by cameras and registered smartphones. When an event is detected, the application notifies the security guards with an alarm sent to their smartphones, and also highlights the event showing a message on the screen of the web system. In addition, a mobile app performs the automatic detection of incorrect and illegal driving vehicles within the facilities of an institution, while letting users generate manual alerts of traffic, security or car accidents. Results from two usability tests proved the applications to be well-accepted by their testers, with a positive overall feedback, calling for attention in two main aspects, the need to place different camera views in different screens (like older systems do) along with some improvements in the search options (for past events).

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