D4.1 A set of flexible modules for sensor data collection, integration and real-time processing.

Interview with Carlos Carreiras & André Lourenço

To explore deliverable 4.1, we will return to our colleagues from CardioID Technologies, where we talk with Carlos Carreiras and André Lourenço. The implementation of the i-DREAMS framework is based on a set of technologies to monitor the context, the driver and the vehicle, and with them assess the 'Safety Tolerance Zone' (STZ). The estimation of the task complexity and coping capacity has to be performed in the vehicle, using an edge computing device in real-time to provide timely interventions to keep drivers in a safe driving zone.

The aim of this deliverable was to describe all the modules for monitoring, integration, real-time processing of information and aggregation in the cloud, collectively entitled as the i-DREAMS platform.

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Hello guys, thank you for taking the time to explain to me all there is to know on D4.1. I will immediately start with my first question. You use sensors to collect data and you use other technology to process this data and to translate all of that into interventions. I assume this requires a serious architecture. Can you explain to us how to imagine that architecture?

Carlos: *"In the i-DREAMS architecture, data from different system components (namely driver capacity, vehicle capacity and task demand) is collected, merged and processed to obtain a real-time assessment of the critical safety risk, which is immediately translated into interventions when required by the situation. Our architecture is built around those system components and is conceived in such a way that it enables the flexible integration of different technologies for data collection."*

What do you mean with 'flexible integration'?

Carlos: *"The architecture is flexible in such a way that, for example, the system does not need to be redesigned from scratch for each mode of transport. It enables the relatively independent implementation of components (vehicle capacity, driver capacity and task demand) such that redesigning one of these components, for example by adding extra complexity, will not affect the other components. The definition of a standardized set of outputs for each component will ensure that other model components, which are dependent on reading these previous outputs, will not be interfered."*

OK, that still sounds a bit fuzzy to me. I want to go deeper into the general architecture. What, exactly, is included in this architecture?

André: *"The architecture of the i-DREAMS platform contains hardware and software of course. The hardware includes both* *monitoring and intervention dimensions, coordinated by the gateway, which is an edge computing device that aggregates all information from the monitoring sensors, computes the STZ and triggers the interventions in the intervention device. We call it 'the brain of the system'. The monitoring sensors can be associated to three perspectives: (1) driver state, (2) task complexity and (3) driving performance. In Figure 1 you can see what we use to monitor each of these perspectives.*

Figure 1: Hardware in-vehicle monitoring components

Furthermore, the i-DREAMS platform uses software, embedded in the gateway (the i-DREAMS on-vehicle software) and cloud APIs for data aggregation/processing (i-DREAMS data processor), post-processing (i-DREAMS post-intervention framework), and front-end (i-DREAMS web platform)."

And do you use the same technology for each mode of transport?

André: *"There are small differences between the modes. Cars are equipped (see Figure 2) with Mobileye and a dashcam, to monitor the road and the driving process and to record events for post-trip analyses. We use a wearable do detect drowsiness/sleepiness, instead of CardioWheel as the last one was found to be less acceptable by drivers due to aesthetical implications. An intervention device is installed, allowing driver identification. Furthermore, this device communicates with the gateway to receive the status of the STZ, providing visual and auditory alerts in real-time. Finally, the i-DREAMS app is made available for installation on the driver's smartphone (Android or iOS), not only to monitor smartphone usage, as an indicator of distraction, but also for post-trip feedback, to engage drivers on improving their performance through a gamification strategy."*

Figure 2: i-DREAMS suite of technologies for cars

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Carlos: *"Most of these technologies are also used in heavy vehicles, although there are some differences. The wearable, for instance, is replaced by CardioWheel in trucks and buses to monitor drowsiness, distraction or inattention. Also, driver identification is done differently compared to cars. We developed an integration with the FMS (Fleet Management System) standard to use an existing system to simplify the driver identification process, namely the tachograph. This device is fitted into trucks and buses and it automatically records speed and distance. Drivers will have to use their ID cards to log their activity, as a legal requirement from transport authorities to check compliance with work regulations. This way, identification in the i-DREAMS platform could be automated."*

Did you also use something different in rail modes?

André: *"Due to technical reasons, we were not able to carry out field-trials for rail modes. The i-DREAMS system turned out not to be compatible with trains, because trains don't do 'line of sight driving' and our system is based on that. And in trams we only tested in the simulator."*

I am still curious about all the different data collection instruments. Would you mind going over them one by one and explain how they work precisely?

Carlos: *"That is no problem. I will start with the gateway, the central element of our system. It allows continuous aggregation of data from the driver's state monitoring sensors, driving/vehicle parameters and road/context monitoring devices. At the same time, it is an edge computing device that calculates the Safety Tolerance Zone (STZ), feeding a Human-Machine Interface, which triggers real-time alarms to the driver. There is also a module that continuously uploads trip data to our web API, for storage and post-trip analysis. Since the beginning of the project, the gateway has evolved, with multiple versions and improvements after testing and validation in simulation and real-world context. The specifications of this system have advanced to allow the robustness needed to accommodate trials in 5 countries and cover different modes of transportation."*

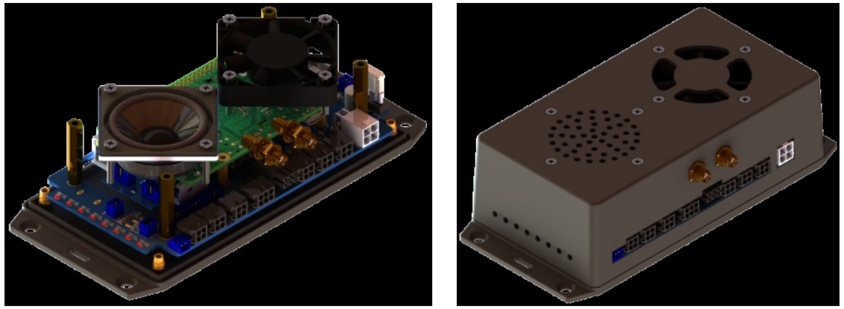

Figure 3: Internal and external view of the gateway

André: "*I will continue with CardioWheel and the wearable, which we both use to get an indication of a driver's drowsiness. CardioWheel is an Advanced Driver Assistance System (ADAS) that acquires the electrocardiogram (ECG) from the driver's hands. When both hands are in contact with the wheel, the signal is acquired. We use it in buses and trucks. The wearable is used as an alternative in cars. It measures the photoplethysmogram (PPG). PPG technology is based on optical measurement of blood flow under the skin. When the heart pumps, the blood flow varies according to the heart's beat frequency. The wearable's sensor detects this variation from the optical signal and translates the data into an accurate heart rate reading with sophisticated algorithms."*

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Figure 4: CardioWheel (left) and wearable (right)

Carlos: *“We also have our cameras: Mobileye and the dashcam. <u>Mobileye</u> is a collision avoidance system that provides drivers with audio and visual warnings of potential hazards on the road, so that they can correct it (e.g., the driver may need to brake in order to avoid a collision). In i-DREAMS, the Eyewatch component of Mobileye wasn’t used, since Mobileye warnings are combined with other inputs and shown in a separate real-time intervention device. This was developed to customize and trigger interventions considering operator status information, which is a key element in the project. The <u>dashcam</u> is a camera that records the road environment in front of a vehicle, providing valuable information on the driving process for post-trip interventions scenarios, where the videos can be used to contextualize the events that are used to score driving behaviour. In these videos, faces and license plates are obfuscated for GDPR (General Data Protection Regulation) compliance.”*

Figure 5: Mobileye, including eyewatch (image 1), Mobileye and dashcam fitted in a vehicle’s windshield (image 2), blurring of license plates (image 3)

André: *“Then we have the <u>intervention device</u>. We already discussed it in-depth in our D4.4 interview, so I will not go into much detail here. The device communicates with the gateway to receive the status of the driver in the STZ and to provide visual and auditory alerts in real-time. Additionally, it is also used for driver identification.”*

Figure 6: Front and back view of the intervention device

Carlos: *“And then lastly, we have <u>FMS</u>. It is our alternative for driver identification. As explained earlier, we use it to automate driver*

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identification in trucks and buses. This might be interesting to know: In 2002, six major truck manufacturers (Volvo, Scania, Iveco, MAN, DAF and Mercedes-Benz) decided to create a standardized vehicle interface for GPS-based tracking systems, that specifies in-vehicle communications of the different types of vehicles. This is what we call the FMS standard. No matter which OEM (Original Equipment Manufacturer) produces a particular vehicle, if it is equipped with an FMS interface, then interface outputs are well known. The standard itself was a huge step forward in fleet management, since telematics devices could access technical vehicle information without the need for vehicle-specific developments."

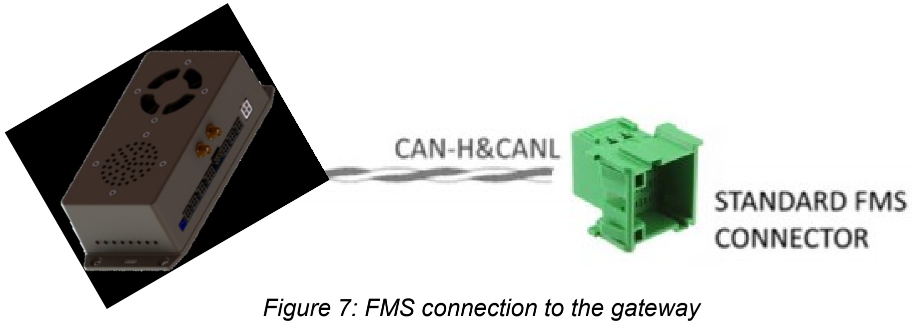

Figure 7: FMS connection to the gateway

Since it is the brain of the i-DREAMS system, let's go back to the gateway. Earlier, you talked about software, embedded in it. Can you elaborate a bit on what that software does exactly?

Carlos: *"That embedded software is crucial for the entire system. Therefore, great care and thought went into its design, taking advantage of open-source, well-supported software components, with the goal of having a robust, modular, and easily maintainable system. This software has 5 major tasks."*

Let's dive into each task then.

Carlos: *"OK, but be careful what you wish for (laughs)! The first task is to collect data from all on-vehicle sensors. This is done in parallel, so the system reads multiple sensors at the same time, and distributes the data to downstream modules that need it. Each sensor produces data with its own communication protocol, its own data format, and its own data rate. On the other hand, data transmission is time-critical, in the sense that important messages (e.g., a collision warning) must be processed in the shortest possible time. Additionally, collected data needs be distributed among several computing modules, which themselves produce output that needs to be sent elsewhere (e.g., to trigger a driver intervention or start a dashcam recording)."*

André: *"The second task is about the STZ computation. Collected data is fed in real-time to the STZ algorithm, triggering driver interventions when needed. The driver user interface control is the component responsible for the third task, which is handling the results from the STZ algorithm. This display controller is also responsible for obtaining the driver identification selected on the display, at the start of the trip. Furthermore, there is also a controller that drives the speaker on the gateway, for auditory warnings."*

Carlos: *"The fourth task is about uploading data. To support post-trip driver interventions and analysis, collected data is stored locally and then uploaded to the i-DREAMS database server. This upload is done either via Wi-Fi or 4G internet connection. For this, a local trip database is maintained on the gateway. Upload attempts are robust to connectivity interruptions, resuming as soon as connectivity is re-established. After upload, trip data is kept on the gateway for 10 days, after which it is deleted."*

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André: *"And last, but certainly not least, there is the task called 'diagnostics and maintenance'. Several mechanisms and tools have been implemented on the gateway to help verify its correct installation and functioning, as well as to assist in issue debugging. Additionally, the gateway periodically checks for software updates. Furthermore, an installer application has been developed. Once connected, the app allows the installer to verify if all hardware interfaces and sensors are working properly. On the gateway itself, a series of software-controlled LEDs indicate the functioning of core components of the gateway. While running, software logs from all modules are kept, including informational as well as error messages. Additionally, system performance parameters are periodically recorded and uploaded. Finally, it is foreseen that CardioID's support team can remotely access the gateway system, to manually assist in resolving any issue."*

There is one more thing that caught my eye while reading D4.1. That was the back-office that was created. Can you tell u something about that?

Carlos: *"To support the installation of the gateway, and the management of the installed equipment in each vehicle, a web back-office was created. The back-office allows each country coordinator to list all the vehicles and verify the status of each gateway.*

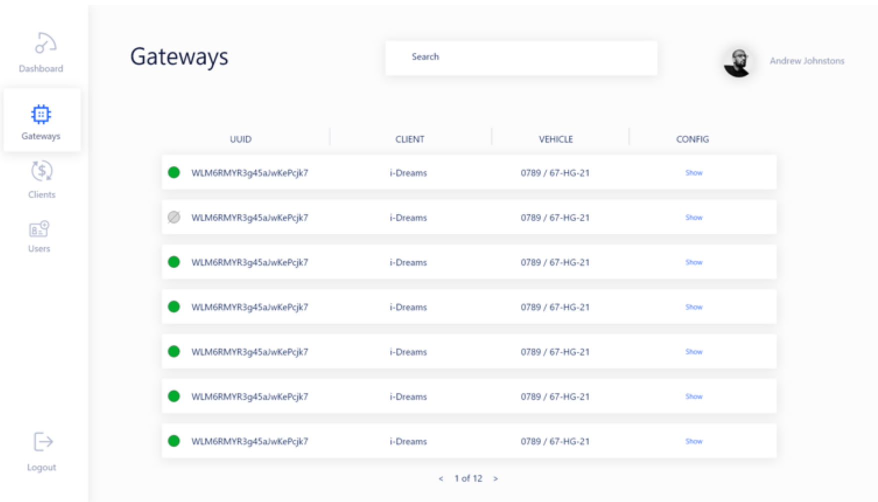

Figure 8: Back-office front-end

Additionally, a mobile application was created to help the installer verify that each system is properly installed (see Figure 9). This application can also be used to capture photos of the installed equipment, to guarantee that each of the systems was correctly installed and that the vehicle was not damaged during the procedure."

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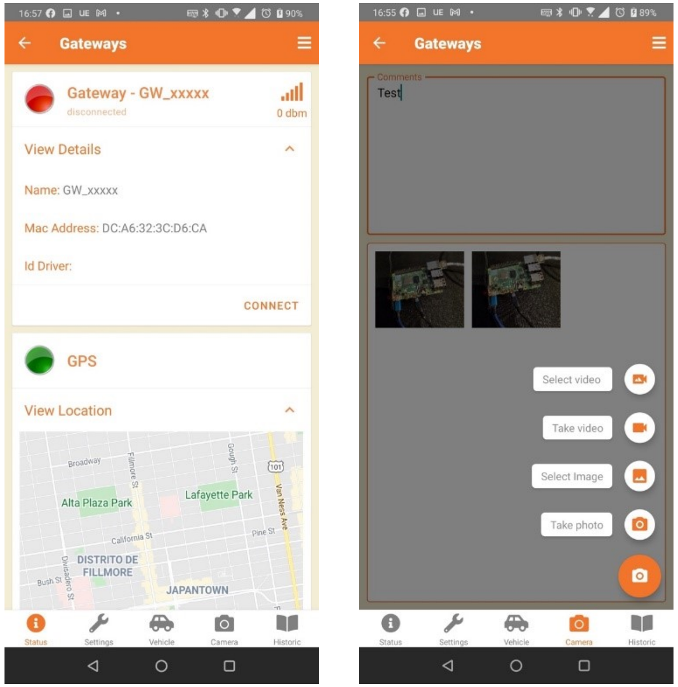

Figure 9: Gateway installation app

OK guys, thank you very much for enlightening me again on all the technical stuff. As always, I am very impressed with all of your work.

Edith Donders

i-DREAMS DisCom Manager

Deliverable 4.1 is part of WP4:

Technical implementation

[Download the report here]

i-DREAMER in the spotlight

CARLOS CARREIRAS

Graduated as *Biomedical Engineer from Instituto Superior Técnico (University of Lisbon) in 2011*

Co-founder and employed at *CardioID since 2015*

Passionate about *signal processing and data analysis, especially when applied to biosignals. I also enjoy reading, watching TV shows, travelling, museums, and going for walks in nature*

Tasks in i-DREAMS: *Development of all Gateway software; validation and testing of hardware Gateway components; integration of STZ algorithm code in the Gateway; development of trip processing web API; integration with i-Dreams web dashboard and data back-office; development of installer app and web back-office; support to installations; member of the i-Dreams Data Knowledge Management Committee*

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