This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 814761

D4.4
A flexible driver-machine interface for real-time warning interventions

Safe tolerance zone calculation and interventions for driver-vehicle-environment interactions under challenging conditions

iDREAMS

Project identification

Grant Agreement No	814761
Acronym	i-Dreams
Project Title	Safety tolerance zone calculation and interventions for driver-vehicle-environment interactions under challenging conditions
Start Date	01/05/2019
End-Date	30/04/2022
Project URL	www.I-Dreamsproject.eu

Document summary

Deliverable No	4.4
Deliverable Title	A flexible driver-machine interface for real-time warning interventions
Work Package	4
Contractual due date	31/12/2020
Actual submission date	23/12/2020
Nature	Other
Dissemination level	Public
Lead Beneficiary	CardioID
Responsible Author	André Lourenço (CardioID)
Contributions from	Carlos Carreiras, David Velez, Lourenço Rodrigues, Cátia Gaspar (CardioID) Tom Brijs (University Hasselt) Bart de Voss (DriveSimSolutions)

Revision history (including peer review & quality control)

Version	Issue date	% Complete	Changes	Contributor(s)
v1.0		0	Initial deliverable structure	André Lourenço
V1.1	30/10/2020	80%	First draft	See 'contributions from' above
V1.2	19/11/2020	100%	Full draft for review	As above
V1.3	10/12/2020	100%	Revised according to internal review	As above
V1.4	22/12/2020	100%	Revised according to external review	As above

Disclaimer

Copyright

Table of contents

List of Figures

List of Tables

Glossary and abbreviations

Word / Abbreviation	Description
ADAS	Advanced Driver Assistant Systems
BLE	Bluetooth Low Energy
CardioGW	CardioID Gateway
FCW	Forward Collision Warning
FTDI	Future Technology Devices International Ltd
GUI	Graphical User Interface
HMI	Human Machine Interface
ID	Identification
LCD	Liquid Crystal Display
LDW	Lane Departure Warning
PCB	Printed Circuit Board
PCW	Pedestrian and Cyclist Collision Warning
P/N	Part Number
STZ	Safety Tolerance Zone
TTC	Time-To-Collision
UART	Universal Asynchronous Receiver/Transmitter
VRU	Vulnerable Road User

Executive Summary

The i-Dreams project hardware infrastructure includes a safety-oriented intervention device - entitled ‘Safety Tolerance Zone’ (STZ) - that aims to inform and warn the driver, in real-time, about the context-aware safety envelope for driving. This device provides visual and sound alerts, information on the state of the STZ, and, for certain situations, collect information about the driver, e.g. identification of the driver.

This document presents the intervention device, justifying the choices for the hardware, embedded software and integration with the gateway.

1 Introduction

1.1 The *i-Dreams* hardware infrastructure

The overall objective of the i-Dreams project is to setup a framework for the definition, development, testing and validation of a context-aware safety envelope for driving ('Safety Tolerance Zone'), within a smart Driver, Vehicle & Environment Assessment and Monitoring System. The materialization of this concept is created by the i-Dreams hardware infrastructure described in D.4.1 (Lourenço, 2020). This infrastructure has both a monitoring dimension, depicted in figure 1, and an intervention dimension.

Figure 1 – Monitoring technologies present on the i-Dreams Hardware infrastructure

The monitoring dimension takes into account the driver background and real-time risk indicators associated with its driving performance, as well as the driver's state and the driving task complexity indicators.

A safety-oriented intervention system will be responsible for effectively informing or warning the driver in real-time. This intervention system is to be conducted by the intervention device, providing visual and sound alerts to the driver, as well as other information about the state of the STZ. Additionally, for certain situations, the intervention device will give specific information to the driver, and also act as an aggregator of information, e.g. identification of the driver.

The scope of this document is to describe the intervention device.

1.2 ADAS & Intervention

Advanced Driving Assistance Systems (ADAS) have been developed to assist drivers in their primary task, i.e. driving, in increasing complex environments. To help the drivers, these systems trigger interventions that can be divided into two categories: active and passive. Passive interventions only inform the driver about road events that need their attention, or other context and car parameters. Conversely, active interventions can take control of the vehicle, not only by accelerating or braking but also managing the lateral position of the vehicle (Rendón-Vélez, 2008). Given the need for renewing homologation of a vehicle after such modifications, active interventions exist only as a built-in feature, while aftermarket options are generally constrained to passive modes.

Passive Intervention ADAS systems are categorized as level 0 of automation, since they only inform the driver of road and car conditions, but do not take any action. An example is Mobileye (Intel Company, 2020), a collision avoidance system, which provides Forward Collision Warning (FCW), Lane Departure Warning (LDW), Pedestrian and Cyclist Collision Warning (PCW). Other systems include parking sensors, cross traffic detection or blind spot information (Galvani, 2019). Intervention mechanisms depend on the event being notified and also on the system providing it.

1.2.1 Forward Collision Warning

Mobileye bases its warnings on the Time to Collision (TTC) parameter, measured through image analysis on a single camera (Dagan et al., 2004). The FCW is preceded by a headway monitoring warning, presented in a display with an image of a green car and the seconds to collision. When the TTC is smaller than a threshold (1.2s) the display changes to a larger image of a red car, while emitting a beeping sound to alert the driver.

Other systems, such as BMW's built-in system, have a similar functioning, using both a camera and a radar. A visual alarm is presented in the control panel as an approximation is detected, and it begins to flash and beep when the TTC is small enough to demand a response by the driver (HLDI, 2019). As a built-in system, it can be coupled with automatic braking, that is deployed in case of inaction by the driver.

Other built-in systems use the same strategy of visual notification upon approximation, and audio when a collision is eminent, such as Mercedes-Benz (Mercedes-Benz, 2015), Audi (Audi Media Center, 2017), or Ford (Ford, 2020a).

1.2.2 Lane Departure Warning

Also based on image analysis, the Mobileye camera detects the lines limiting the lane where the driver is located and, if the driver crosses them without signalling, sounds a series of beeps while presenting a pictogram of such lanes.

BMW, however, notifies the driver of non-signalled lane departures by vibrating the steering wheel, offering also active options such as lane keeping assistance, where the direction of the car is locked to follow the current lane, unless blinkers are activated (HLDI, 2019).

Mercedes-Benz, Audi and Ford (Ford, 2020b) use a similar strategy, vibrating the steering wheel when the driver starts crossing the lane markings without signalling with the blinkers, as well as .

1.2.3 Pedestrian and Cyclist Collision Warning

By detecting vulnerable agents and tracking their movement to perceive if their path collides with the vehicle's path, Mobileye is able to produce a warning similar to FCW, where a series of beeping sounds is prompted, while a red icon of a pedestrian is shown in the display unit (Shashua, 2004).

Again, BMW provides a similar system, alerting the driver of a pedestrian in its path by visual and audio stimuli (pedestrian icon on the control panel and repeating beeps). BMW also prepares the brakes to maximize the braking response once the driver triggers the pedal and can also automatically activate them if the driver takes too long to react (BMW pressclub, 2014).

Ford includes pedestrian detection in its forward collision warning system.

1.2.4 Traffic sign detection alert

Another characteristic of the environment that camera-based systems can collect is the information regarding road signs, especially speed limits. Mobileye uses this to display the current speed limit, enlarging the displayed sign if the driver exceeds it. Audi uses a similar strategy (Audi Canada, 2020), while manufactures such as BMW and Ford display the detected signs but take no action if speed limits are crossed (BMW manuals, 2012; Ford, 2020c).

1.2.5 Fatigue and Drowsiness alert

Acknowledging the increased risk of driving while drowsy or fatigued, for both the driver and other agents on the road, some car manufactures have developed systems capable of detecting changes in the driver behaviour and taking measures to ensure protective behaviour and/or increased attention.

Ford integrates this in its lane keeping assistant, by detecting lane drifting and getting the driver's attention with the steering wheel vibration. Mercedes combines measures of steering wheel behaviour, interaction with the car's dashboard and time in the wheel to emit audio signals that alert the driver, while prompting messages asking them to take a break (Hanley, 2015). Other companies rely on the steering wheel dynamics to detect drowsiness and fatigue, such as Nissan and BMW, which present audio cues and an icon of a coffee cup on the control panel to suggest that the driver should stop the car and rest before continuing driving (CARS.COM, 2016).

1.3 Deliverable overview and report structure

The main aim of this deliverable is to describe the intervention device, to present the rationale behind the decisions, and document all the components of its hardware.

Section 1 outlines the i-Dreams hardware infrastructure, with an overview on ADAS and the types of intervention they can provide, comparing Mobileye to other built-in systems. Sections 2 and 3 detail the design and present the main features of the intervention device, with specifics on its hardware components. Section 4 breaks down the graphical user interface of the device that prompts the driver to confirm his/her ID and displays real-time information and interventions, if necessary. Finally, Section 5 addresses the integration with CardioGateway, which sends commands to the display and also triggers the real-time intervention warnings.

2 Intervention Device

The intervention device is a customized integration of a LCD capacitive touch display embedded system that communicates with the CardioID Gateway (CardioGW) to receive the status of the STZ.

The design of this device was constrained by the available budget, while guaranteeing ease of installation, good usability, and production efficiency. Based on these requirements, components were selected, and a prototype design was made, built, and validated (DSS Team, 2020). This prototype led to the creation of a final design, shown in Figure 2 and herein described, aiming at industrial replication.

Figure 2 – Intervention device front and back views.

The intervention device has the capability to give visual alerts through a display, and auditory interventions in conjunction with CardioGW. It was designed around a Nextion 2.4 inch HMI display, chosen based on price-technical specifications.

The device can be glued to the windscreen or the cockpit using a custom support, with a 3M adhesive. One automotive-grade Molex connector is used to wire the device to the CardioGW (more details in Section 3). The casing allows this connector to be placed either on its left or right side, which simplifies the installation both in right-hand and left-hand traffic vehicles.

3 Hardware Description

The intervention device is composed of the parts described in Figure 3, and table 1

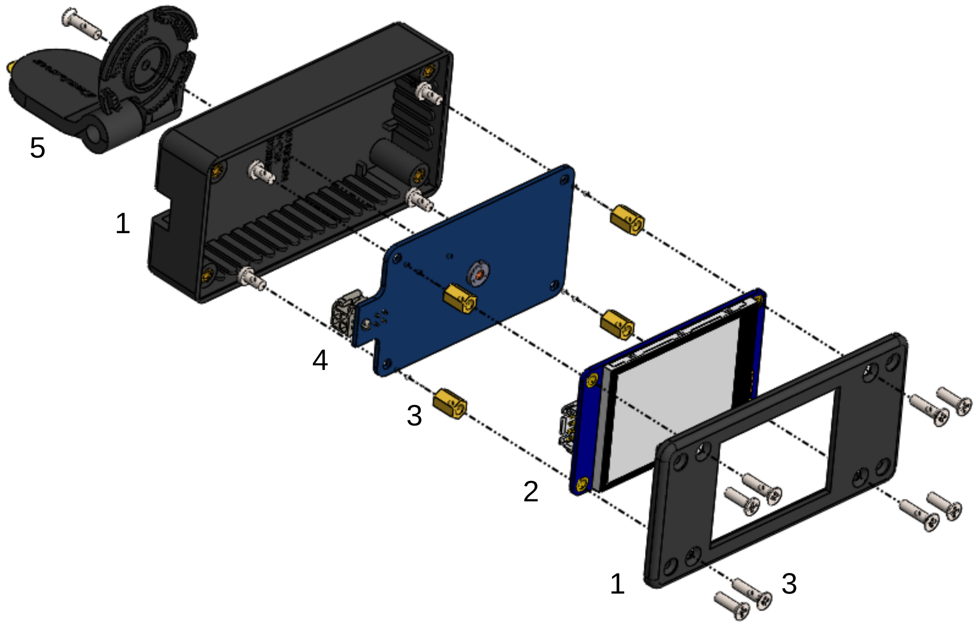


Figure 3 – Breakdown of the intervention device.

Table 1 – Intervention Device hardware parts

Item	Description
1	Enclosure
2	Nextion 2.4 inch display
3	Machine screw M3x10 countersuck head
4	PCB intervention device V1.0
5	Custom support V1.0

3.1 Display

The Nextion HMI display is a complete HMI solution that can be easily programmed to show a wide range of visual warnings in full colour. It was selected based on previous use cases, specifications, availability, and price.

The device combines a touch-sensitive LCD screen with an onboard controller and memory. This means that it does not require a video signal. Instead, the device can be programmed with a custom routine and pre-defined pictures and screens. These pre-defined pictures and screens can be called through a UART serial interface, which makes the device compatible with a wide range of other controllers and devices, including the CardioID GW. Using simple serial messages to control the display device instead of a video signal, also reduces processing and graphical load on the i-Dreams gateway.

Another advantage of using a complete solution with internal controller is that the HMI device can run its own routine without connection to other controllers. Within the i-Dreams system this is especially important during the start-up phase, right after the vehicle's ignition switch has been turned on. The Nextion device boots up almost instantly and can prompt the driver with a message to confirm his/her ID before the bootup sequence of the I-Dreams gateway is fully completed.

3.2 PCB

The decision to design a custom printed circuit board (PCB) that integrated the electrical connector was made to guarantee the industrial and scalable replication of the device. As shown in Figure 4, it consists of a single-layer PCB interfacing the Molex connector to the display itself through an serial to TTL FTDI circuit. Additionally, a mechanical connection with the casing and custom support is included.

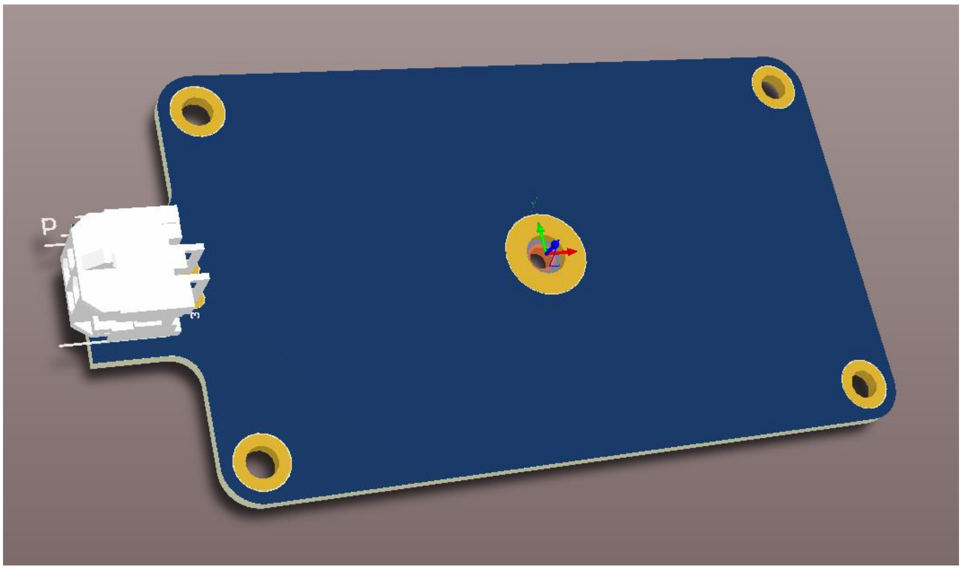


Figure 4 – Custom PCB

3.3 Mechanical Interface

Due to pricing and number of devices to be produced, the enclosure was decided to be based on an off-the-shelve product that could be drilled according to a custom design. The front cover has different mechanical connections with the display and the PCB, while the base case has the mechanical connection with the support, as shown in Figure 5. The support allows axial and yaw rotation.

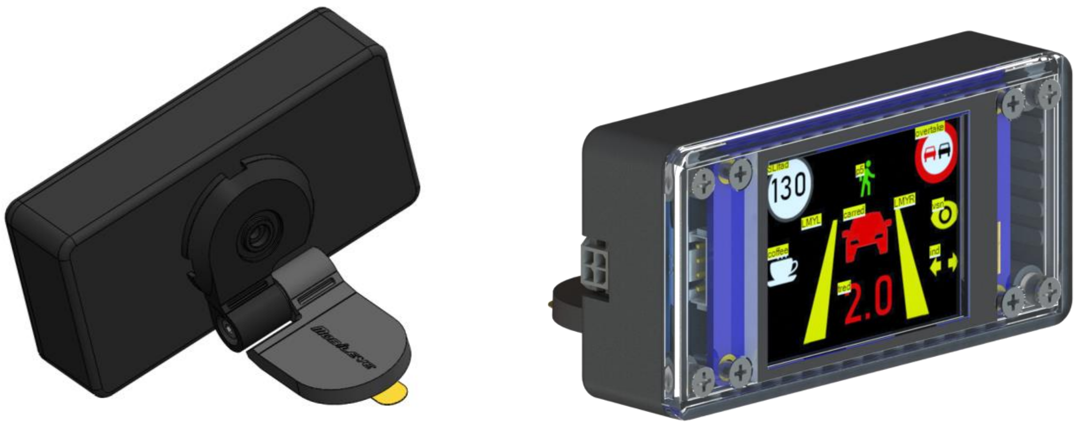


Figure 5 – Support and front cover of the intervention device.

Weight	250 g
Dimensions	99mm x 51 mm x 20 mm
Ingress Protection	IP54
UL flammability rating	UL94 V-0

3.4 Connectors

Connector: Molex Micro-Fit 3.0, P/N 43045-0400
Use With: Molex P/N 43025-0400 and Molex P/N 43030

Figure 6 – Front view of the receptacle

Pin	Description
1	VBUS
2	Ground
3	Data +
4	Data -

4 Graphical User Interface (GUI)

The GUI design can be separated into two different sections. Firstly, driver identification and settings. Secondly, real-time interventions.

After turning on the ignition switch, the driver will be automatically prompted with a message to confirm or change his/her driver ID. After the driver ID has been confirmed and communication with the i-Dreams gateway has been established, the intervention device will display an interface that provides the driver with real-time information and, if necessary, displays visual real-time interventions.

4.1 Driver Identification

When the driver turns on the vehicle's ignition switch, the intervention device boots up almost instantly. The driver will see a message displayed on the screen to confirm or decline whether the last known driver is also the current driver, as depicted in Figure 7.

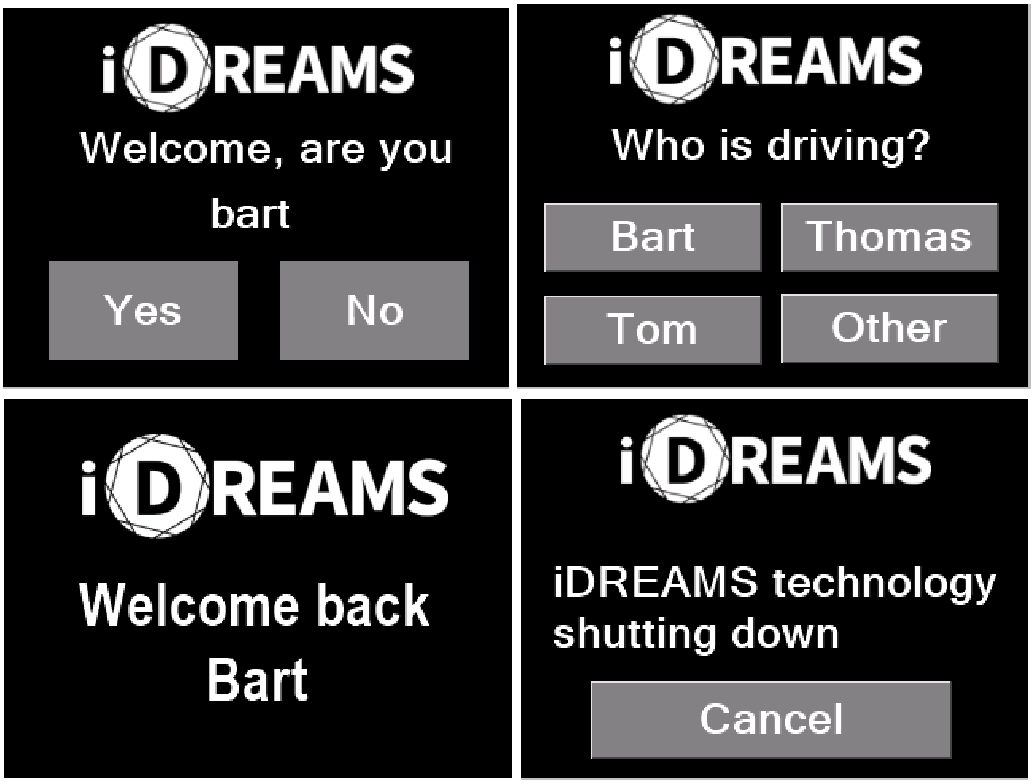


Figure 7 – Driver identification GUI screens

The driver has the option to confirm, which will trigger a welcome screen, or decline, which will bring up a list of drivers that are known for the current vehicle. Selecting one of the IDs from this list also triggers the welcome screen, while pressing the "Other" button confirms that the driver is not enrolled in the i-Dreams program, triggering a message that warns the driver that the intervention device is about to be shut down.

Once the welcome screen is displayed, the intervention device waits for the i-Dreams gateway to boot up. When communication has been established between the i-Dreams gateway and the intervention device, the real-time interventions GUI will be loaded. Otherwise, the intervention device will be deactivated.

4.2 Real-time interventions

The approach for the design of a real-time intervention GUI was to use a main page where the driver is presented with relevant, non-safety-critical information in real-time. Such system includes information about the current status of safety monitoring systems, traffic sign and speed limit information, as well nudging mechanisms that promote safer driving.

Interventions that are time-critical and demand immediate action have a dedicated view and take over the entire screen. Usually, they are also accompanied by an auditory alert.

Changes in traffic laws, such as a change of speed limit, also trigger a temporary popup on the entire screen, unless more important information is currently available.

4.2.1 Main page

On the main page, visual information about the different safety monitoring systems is presented to the driver as symbols. A screenshot of the main screen with symbols for all the different monitoring systems is shown in Figure . Each symbol is linked to a specific monitoring system (headway, lane keeping, fatigue…) and different colours are used to show the current status or phase and nudge the driver to stay within the normal driving phase of the safety tolerance zone.

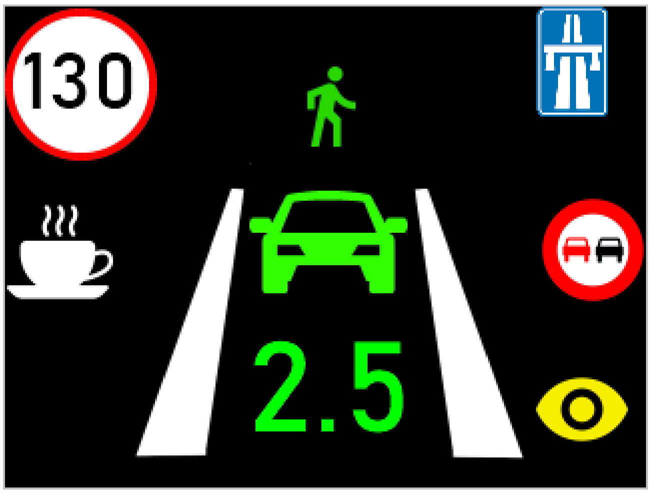
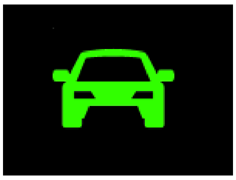
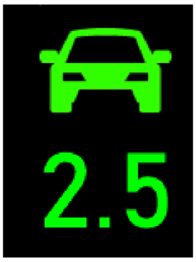
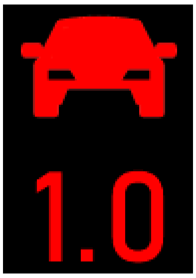
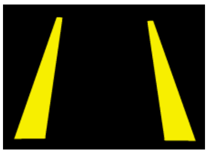
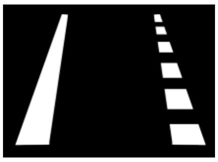
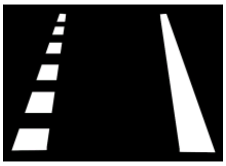
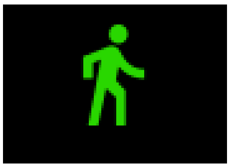
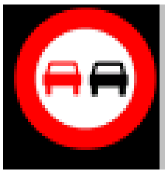
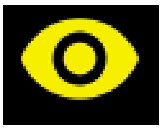
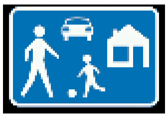


Figure 8 – Real-time interventions GUI: main page

An overview of the different symbols that can be exhibited on the main page is provided in Table 2.

Table 2 – Real-time intervention GUI: Main page symbol overview

Symbol	Meaning
	Headway Monitoring: Vehicle detected ahead.
	Headway Monitoring: Vehicle detected ahead and driving at a safe distance. Time headway is displayed.
	Headway Monitoring: Vehicle detected ahead, time headway to the vehicle is unsafe. Time headway is displayed. When time headway is below the first threshold, a static red car is displayed. When a second threshold is passed, the red car symbol is blinking.
	Lane departure monitoring: No road markings detected.
	Lane departure monitoring: Road marking detected.
	Lane departure monitoring: Lane departure warning on the right-hand side is active. Crossing right-hand side markings without turn indicator usage.
	Lane departure monitoring: Lane departure warning on the left-hand side is active. Crossing left-hand side markings without turn indicator usage.
	VRU monitoring: Vulnerable road user detected.

Symbol	Meaning
	Speed limit indication and monitoring: displays the latest speed limit traffic sign.
	Speed limit indication and monitoring: displays the latest speed limit traffic sign. Current speed is above the speed limit.
	Fatigue and sleepiness monitoring: Fatigue is detected, first stage.
	Fatigue and sleepiness monitoring: Fatigue is detected, second stage. Symbol is flashing on and off.
	Illegal overtaking monitoring: A no-overtaking sign has been detected.
	Visibility: Poor visibility
	Traffic Sign Recognition: Certain traffic signs can be recognized and displayed on the main screen.

4.3 Dedicated views

4.3.1 Time critical warnings

For warnings that are time-critical and require action from the driver, a dedicated view is used, in which the symbol takes over the entire screen. The symbols are similar to those used on the main page but are larger and more intrusive. Table 3 shows an overview of the possible dedicated views for time-critical warnings.

Table 3 – Overview of the dedicated views for time-critical warnings

View	Meaning
	Headway Monitoring: Forward Collision Warning. Symbol is blinking
	VRU Monitoring: Pedestrian Collision Warning. Symbol is blinking
	Speed Limit indication and monitoring: There are 2 stages of over speeding: During the first stage, the symbol is displayed statically for 1s. During the second stage, the symbol is blinking for 1s.
	Fatigue and sleepiness monitoring: Shown for 1s when the first stage of fatigue is first detected.
	Fatigue and sleepiness monitoring: Shown for 1s when the second stage of fatigue is first detected.
	Illegal overtaking monitoring: An illegal overtaking action is currently being performed.

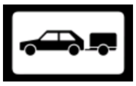
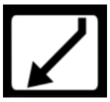
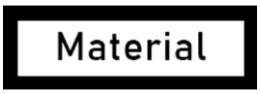
4.3.2 Traffic sign recognition

The Mobileye system can read certain traffic signs and supplementary sign (if present). Whenever a new traffic sign is read by Mobileye, it will be shortly displayed on the intervention device on the full screen, provided that no safety-critical conditions are active. Table 4 shows an overview of the traffic sign symbols, while Table 5 shows an overview of the supplementary traffic signs

Table 4 – Traffic sign symbols overview

Symbol	Meaning
	Displays the new speed limit
	End of speed limit sign detected.
	Start of motorway sign detected
	End of motorway sign detected
	Start of expressway sign detected
	End of expressway sign detected
	Start of playground sign detected
	End of playground sign detected
	Overtaking restriction sign detected

Table 5 – Supplementary traffic signs overview

Symbol	Meaning
	Supplementary sign trailer
	Supplementary sign rain
	Supplementary sign snow
	Supplementary sign time restriction
	Supplementary sign exit left
	Supplementary sign exit right
	Supplementary sign bending left
	Supplementary sign bending right
	Supplementary sign truck
	Supplementary sign distance for
	Supplementary sign distance in
	Supplementary sign weight
	Supplementary sign tractor
	Supplementary sign snow/rain
	Supplementary sign fog
	Supplementary sign hazardous material
	Supplementary sign night

5 Integration with CardioGW

As described in the previous sections, the Nextion display runs its own user interface application. However, to activate and deactivate the different screens, images, and warnings, in response to the changing phases of the STZ algorithm, this display needs to send and receive commands from the CardioGW. This is done physically via the serial UART interface of the CardioGW.

On the CardioGW side, a software controller module was developed. This module is part of the data distribution network (described in Deliverable D4.1), receiving messages from the STZ algorithm, speed limit information, and traffic signs, which then activate the appropriate visualizations on the display. This controller module also triggers the warning sounds associated with each intervention situation, through the use of a speaker on the CardioGW.

Additionally, a special mechanism was developed for the purpose of driver identification (in the car scenario) On one hand, this mechanism is in charge of verifying which driver is at the wheel. On the other hand, it is responsible for accepting the incoming real-time data from the driver's OSeven mobile phone application. This is an important issue in use cases where multiple participants use the same vehicle and happen to be in the vehicle at the same time (e.g. a car shared among family members). An overview of this mechanism is presented in Figure 9.

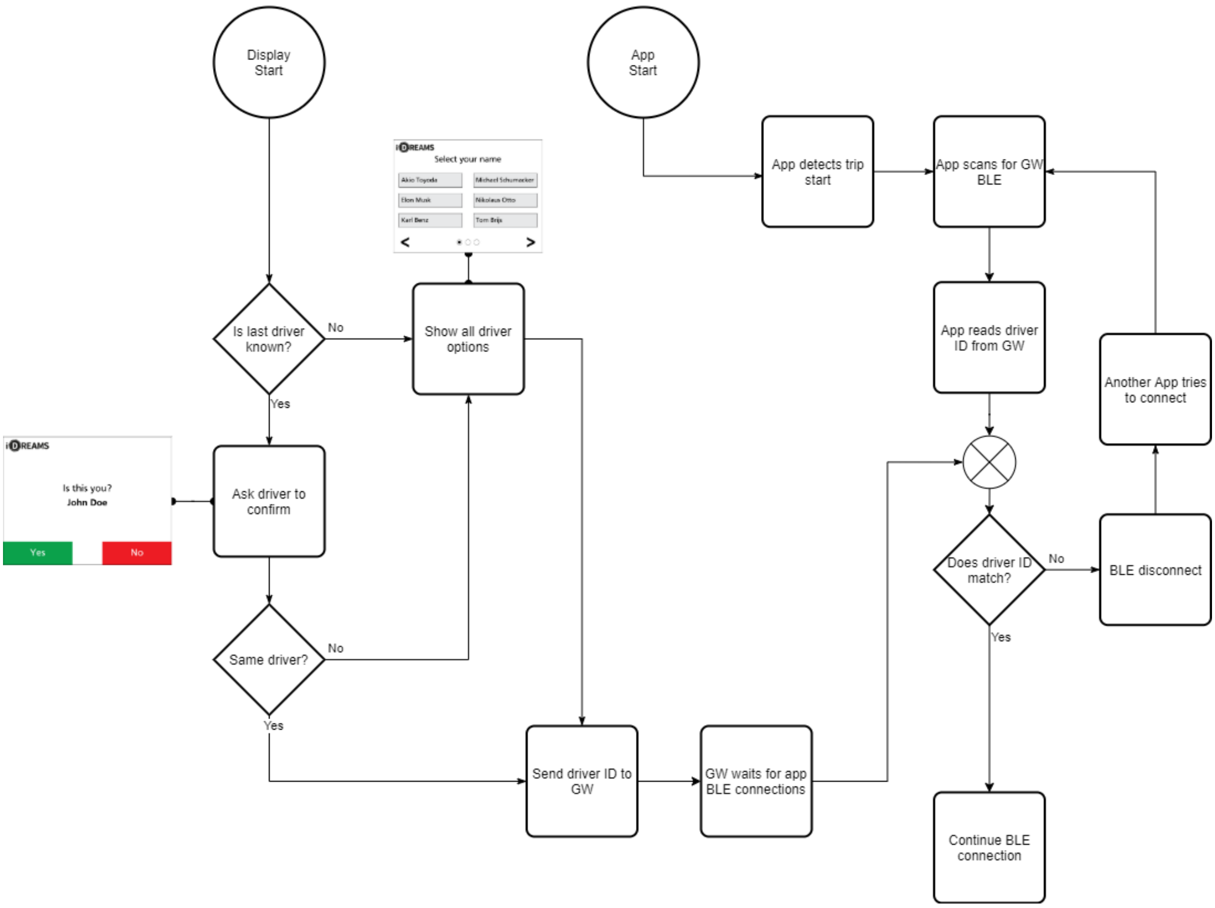


Figure 9: Overview of the driver identification mechanism.

Starting with the display, which boots up quickly, drivers are presented with the option to verify if they were the last user of the vehicle, or to select a driver from the presented list. The confirmed driver identification is then sent to the CardioGW, which starts a BLE service advertising the corresponding driver ID. Once the OSeven app detects the start of a trip, it will look for a CardioGW to connect to and verify if its internal user matchs the one advertised by the CardioGW. If it matches, the OSeven app starts to send real-time data from the mobile device to the CardioGW, via BLE.

This mechanism also supports the use case in which the driver does not select an ID, which results in no recording the trip data. This may happen whenever the driver is not a participant or does not want a specific trip to be recorded, thus preserving user privacy.

6 Conclusions and implications

The intervention device was designed and its prototype was built according to the specifications, having been successfully validated in a simulation environment. At the end of 2020, it will be tested in two test vehicles (Hasselt and CardioID teams). There are no planned delays for the production at the end of 2020.

References

Lourenço, A. Carreiras, C., Velez D., Gaspar. C, Brijs, T. (2020). *A set of flexible modules for sensor data collection, integration and real-time processing,* Deliverable 4.1 of the EC H2020 project *i*-DREAMS.

Rendón-Vélez, E., Horváth, I. & Opiyo, E. Z. (2008) Current Progress in Advanced Driver Assistance Systems : A Structured Analysis. in TMCE 2008.

Intel Company (2020), Mobileye collision avoidance System, retrieved from https://www.mobileye.com/ on 20/12/2020

Galvani, M. (2019) History and Future of Driver Assistance. EEE Instrumentation and Measurement Magazine, 22(1), ISSN: 19410123

Dagan, E., Mano, O., Stein, G. P., Shashua, A. (2004) Forward collision warning with a single camera. in IEEE Intelligent Vehicles Symposium, Proceedings 2004, doi: 10.1109/ivs.2004.1336352

Highway Loss Data Institute (HLDI), 2013–17 BMW collision avoidance features. Bulletin, vol. 36, no.37; December 2019.

Mercedes-Benz. (2015,04 15). By far the best: Mercedes-Benz assistance systems. Mercedes-Benz, retrieved from https://www.mercedes-benz.com/en/innovation/autonomous/by-far-the-best-mercedes-benz-assistance-systems/ on 29.10.2020

Shashua, Y. Gdalyahu and G. Hayun, "Pedestrian detection for driving assistance systems: single-frame classification and system level performance," IEEE Intelligent Vehicles Symposium, 2004, Parma, Italy, 2004, pp. 1-6, doi: 10.1109/IVS.2004.1336346.

BMW pressclub (2014,12 10). Pedestrian Warning with City Braking Activation from BMW ConnectedDrive receives Euro NCAP Avanced award 2014. Press BMW Group, retrieved from https://www.press.bmwgroup.com/global/article/detail/T0197906EN/pedestrian-warning-with-city-braking-activation-from-bmw-connecteddrive-receives-euro-ncap-advanced-award-2014?language=en on 29.10.2020

Audi Media Center (2017, 02 17) Driver assistance systems. Audi Media Center, retrieved from https://www.audi-mediacenter.com/en/technology-lexicon-7180/driver-assistance-systems-7184 on 29.10.2020

Ford Motor Company (2020) Pre-Collision Assist with Automatic Emergency Braking. Ford, retrieved from https://www.ford.com/technology/driver-assist-technology/pre-collision-assist/ on 29.10.2020

Ford Motor Company (2020) Lane-Keeping System. Ford, retrieved from https://www.ford.com/technology/driver-assist-technology/lane-keeping-system/ on 29.10.2020

Ford Motor Company (2020) Traffic Sign Recognition System. Ford, retrieved from https://www.ford.co.uk/shop/research/technology/driving-experience/traffic-sign-recognition-system on 29.10.2020

BMW manuals (2012) Speed limit detection with NoPassing information: the concept. BMW manuals, retrieved from http://www.bavarianmw.com/guide-3218.html on 29.10.2020

Audi Canada (2020) Traffic Sign recognition. Audi Canada, retrieved from https://www.audi.ca/ca/web/en/search-terms/Traffic-Sign-Recognition.html on 29.10.2020

CARS.COM (2016, 04 16) Drowsy Driver Detection Systems Sense When You Need a Break. CARS.COM, retrieved from https://www.cars.com/articles/drowsy-driver-detection-systems-sense-when-you-need-a-break-1420684409199/ on 30.10.2020

Hanley, M. (2015, 05 05) Asleep at the Wheel? Not With Mercedes' Attention Assist. CARS.COM, retrieved from https://www.cars.com/articles/asleep-at-the-wheel-not-with-mercedes-attention-assist-1420680393764/ on 30.10.2020

DSS Team (2020) Intervention device prototype, Idreams interal document