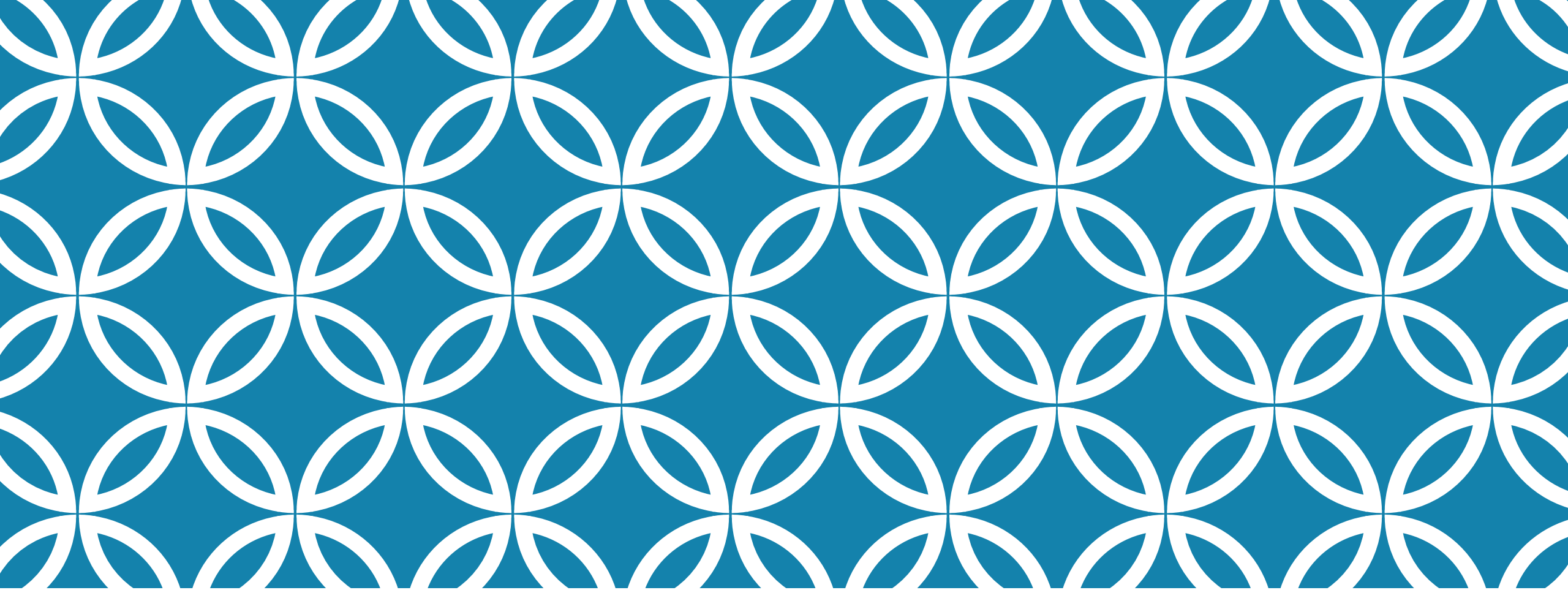
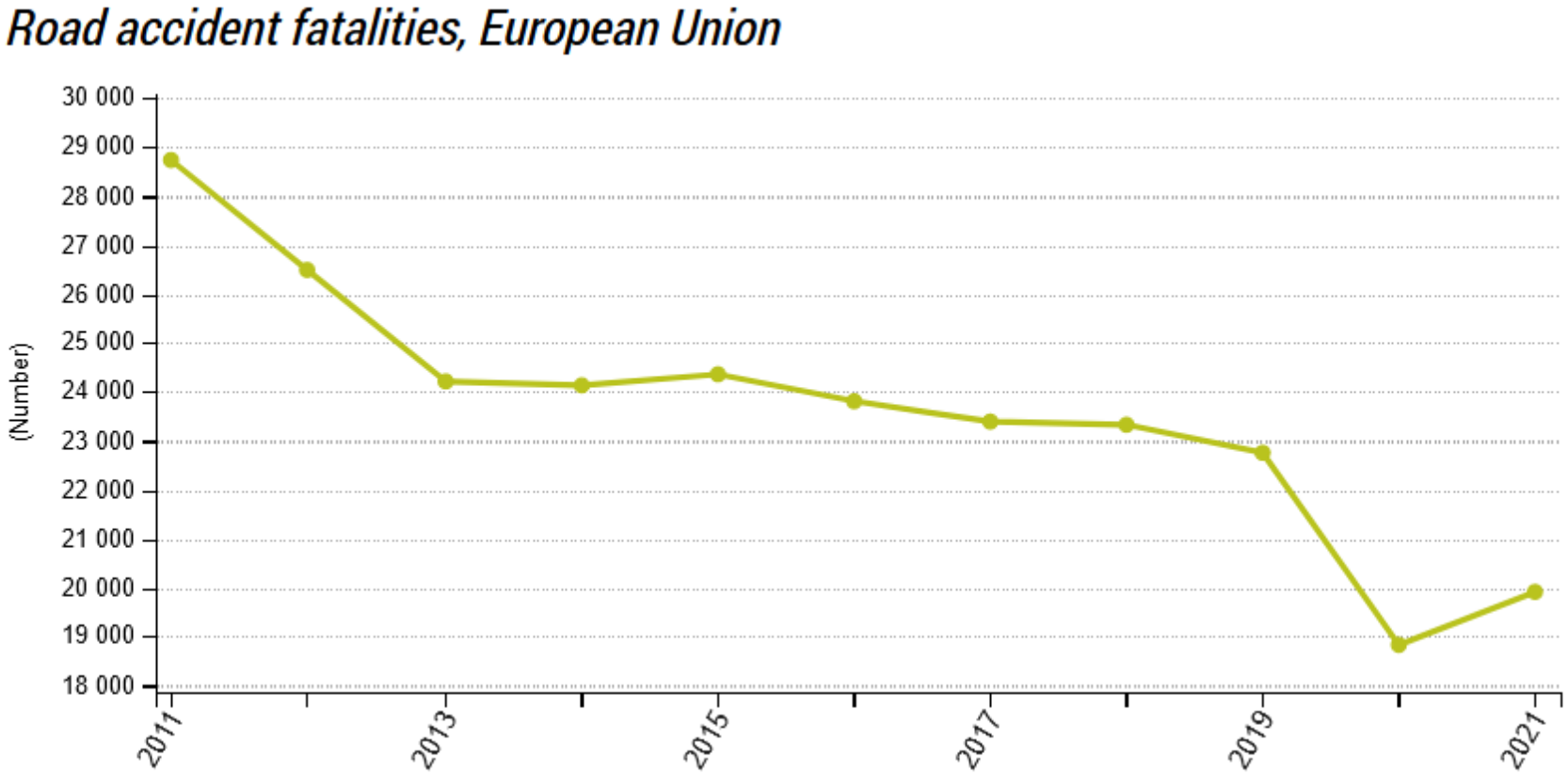


# SAFETY DRIVING RECOGNITION

Federico Cavedoni
Francesco Bruno

# SAFETY DRIVING RECOGNITION




https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20230620-1

# SAFETY DRIVER CONDITIONS MONITORING

Our Goal is trying to reduce the number of accidents by analysing:

- Driver distraction
- Driver drowsiness
- Driver medical conditions.

# STATE OF THE ART (1/4)

**T-Mate by Toyota**

- Emergency Detection Stop System
- Driver Monitor Camera
- Rear Passenger Detection


https://www.toyota.it/mondo-toyota/sicurezza

# STATE OF THE ART (2/4)

- **ATTENTION-ASSIST by MERCEDES-BEN**


- **DRIVE ASSIST by PEUGEOT**

# STATE OF THE ART (3/4)

- **DRIVER ALERT by FORD**


# STATE OF THE ART (4/4)

- **Design of Smart Steering Wheel for Unobtrusive Health and Drowsiness Monitoring**
  https://www.mdpi.com/1424-8220/21/16/5285

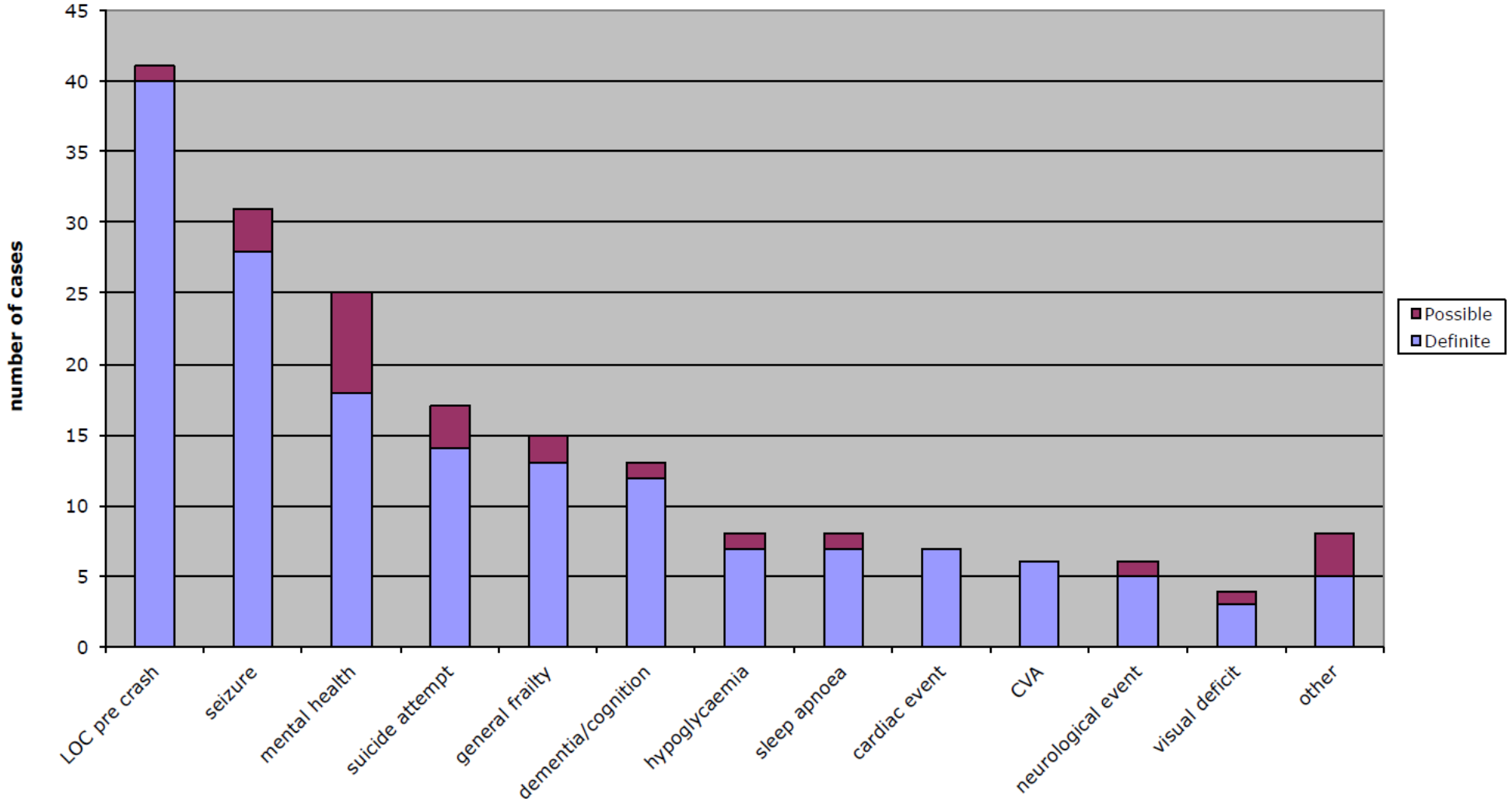
- **Driver Vital Signs Monitoring Using Millimeter Wave Radio**
  https://ieeexplore.ieee.org/abstract/document/9615374?casa_token=M6LXft8mKGAAAAAA:6q_D-AZFErSj8-zDADY9Jr3E5jsF9uk2_-fL5LMsdKS0VvmRgMZI1-khlwde__6VOq2k_gxUew

- **Driver Distraction Detection on Edge Devices via Explainable Artificial Intelligence (UNIPI)**
  https://www.iiis.org/DOI2023/SA300MJ/

# MARKET ANALYSIS

| | Vital Signal Monitoring | Rear Passenger Detection System | Driver Distraction Detection |
|---|---|---|---|
| T-MATE | ✗ | ✓ | ✓ |
| ATTENTION ASSIST | ✗ | ✗ | ✓ |
| DRIVER ALERT | ✗ | ✓ | ✓ |
| DRIVE ASSIST | ✗ | ✗ | ✓ |

# HEALTH-RELATED CAR ACCIDENT CAUSES




https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjT8sfNxeuCAxUdSfEDHcBeD2AQFnoECBkQAQ&url=https%3A%2F%2Fcasr.adelaide.edu.au%2Fcasrpubfile%2F1151%2FCASRmedicalconditionscrashcausation-1253.pdf&usg=AOvVaw1w0m53NVsb3qGhGR1NHdpB&opi=89978449

# TECHNOLOGIES ANALYSIS

| | Syncope | Seizure | Hypoglicaemia | Drowsiness | Hearth Attack | Stroke |
|---|---|---|---|---|---|---|
| **PPG** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **ECG** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **IR CAMERA** | ✗ | ✓ | ✗ | ✓ | ✗ | ✗ |
| **RADAR** | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |

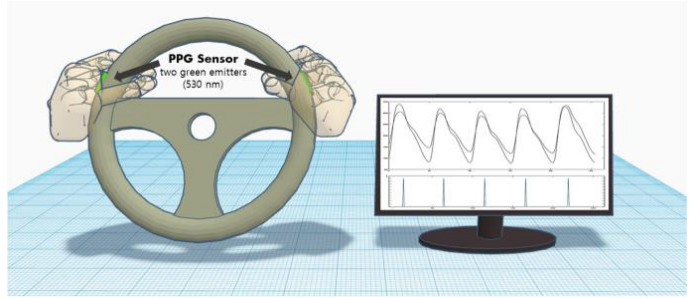
# USER SPECIFICATIONS

- The system must be not invasive
- The system must be user-adaptable
- The system periodically get data from sensors
- The system classifies the obtained data
- The system takes decisions based on classified data

# PRODUCT SPECIFICATIONS

- The sampling process must not distract the driver
- The vital parameters must be specific for each user
  https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6147850/
- The classification must have an high precison (80%)
  https://www.mdpi.com/2073-431X/10/12/158

# ENABLING TECHNOLOGIES (1/2)

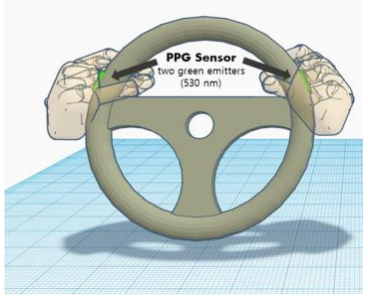



- Periodic data collected by PPG sensor
- Data classified with LSTM Neural Network
  https://ieeexplore.ieee.org/document/9573888
- The classification parameters are user-specific

# ENABLING TECHNOLOGIES (2/2)

PPG Sensor:

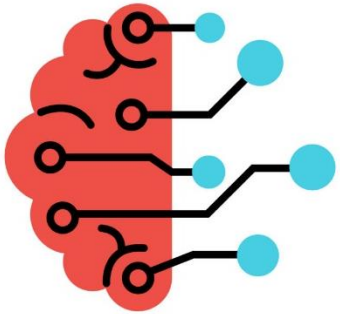
- Less invasive respect to ECG
- Used to obtain Hearth Rate Variability (HRV)



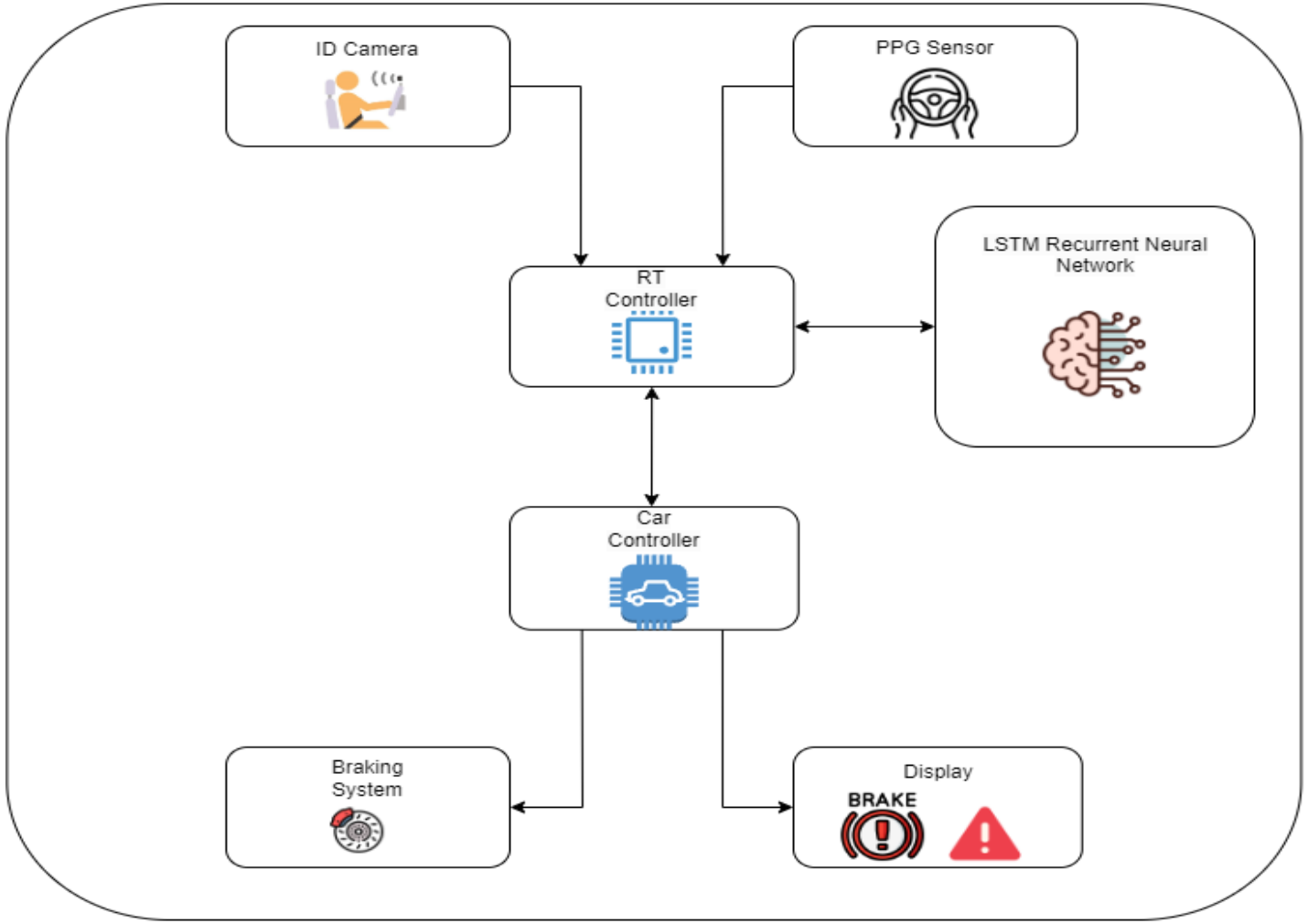

LSTM Neural Network:

- Better performance during testing
- No pretrained solutions

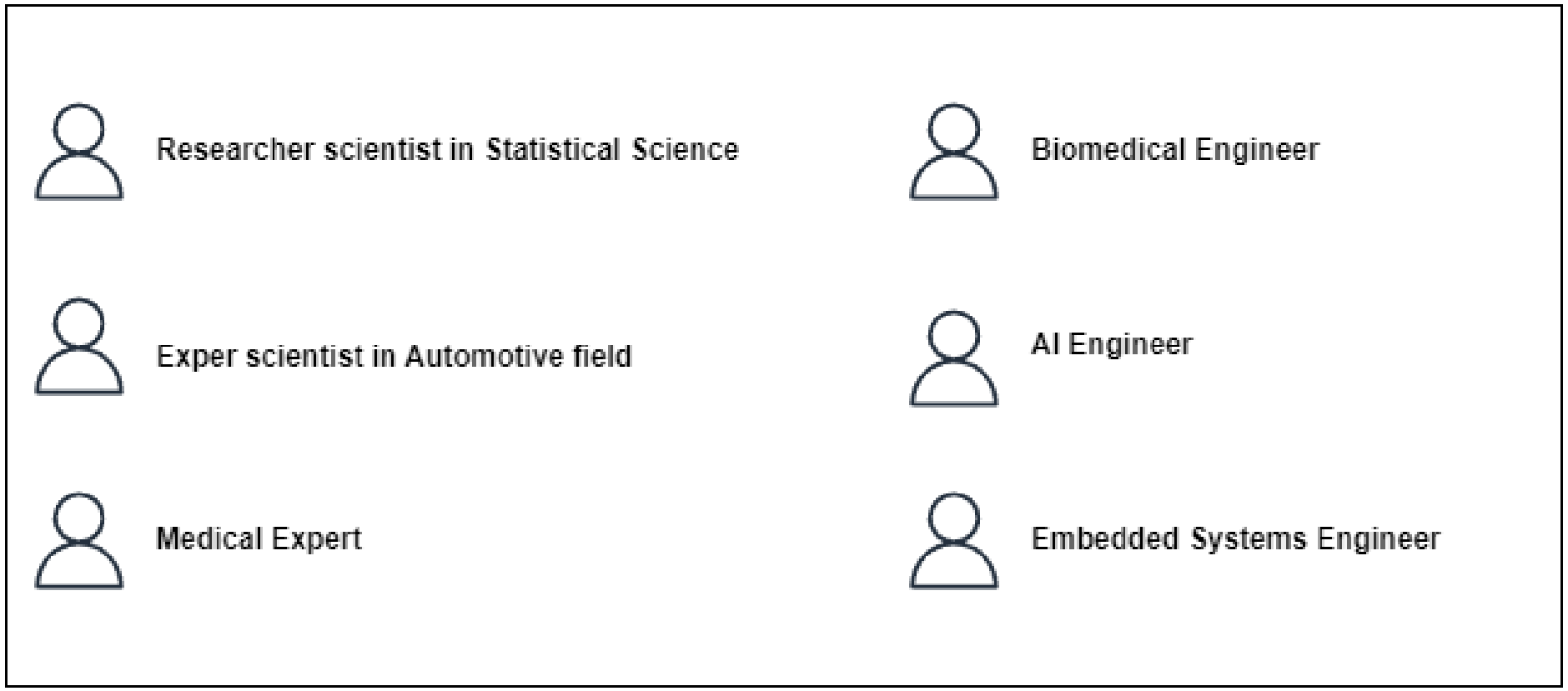
https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9807511



# PRODUCT ARCHITECTURE



# PROFILE ANALYSIS



# WORK PACKAGE 1 (1/4)

| WP 1 | **WP Title:** Analysis of factors that increase driving danger<br><br>**WP Type:** R.I. | **Activity Start:** Month 1 | **Activity End:** Month 2 |
|---|---|---|---|
| **Man/Month:** 0.3 + 0.6 + 0.3 + 0.3 = 1.8 Man/Month | | | |
| **Objectives:**<br><br>• Identification of the main causes of accidents<br>• Understand what technologies exist to improve driving safety<br>• Understand what are the most frequent causes related to driver health problems<br>• Understand what technologies can detect the most frequent health problems that lead to accidents | | | |

# WORK PACKAGE 1 (2/4)

**Activities:**

- Analysis of the most common accidents causes
- Market analysis
  - Analysis of actual used technologies (State of Art study)
- Analysis of accident rates caused by sickness
- Study of key monitoring technologies on driver status

# WORK PACKAGE 1 (3/4)

**Roles hours per Task:**

1) Analysis of the most common accidents causes (Month 1)
    - Researcher scientist of Statistical Science. Approx: 50 hours (0,3 man/month)

2) Market analysis (Month 1)
    - Expert scientist in Automotive field. Approx: 100 hours (0,6 man/month)

3) Analysis of accident rates caused by sickness (Month 2)
    - Researcher scientist of Statistical Science. Approx: 50 hours (0,3 man/month)

4) Study of key monitoring technologies on driver status (Month 2)
    - Medical Expert. Approx: 50 hours (0,3 man/month)
    - Embedded Systems Engineer. Approx: 50 hours (0,3 man/month)

# WORK PACKAGE 1 (4/4)

**Costs:**

- Researcher scientist of Statistical Science. Approx: 100 hours (0,6 man/month)
  - €20 per hour x 50 hours = €1.000
  - €20 per hour x 50 hours = €1.000
- Expert scientist in Automotive field. Approx: 100 hours (0,6 man/month)
  - €20 per hour x 100 hours = €2.000
- Medical Expert. Approx: 50 hours (0,3 man/month)
  - €30 per hour x 50 hours = €1.500
- Embedded Systems Engineer. Approx: 50 hours (0,3 man/month)
  - €40 per hour x 50 hours = €2.000

**Total Cost: €7.500**

# WORK PACKAGE 2 (1/4)

| WP 2 | **WP Title:** Preliminary product analysis<br>**WP Type:** R.I. | **Activity Start:** Month 3 | **Activity End:** Month 5 |
|---|---|---|---|
| **Man/Month:** 0.6 + 0.6 + 0.6 + 0.6 + 0.6 = 3.0 Man/Month | | | |
| **Objectives:**<br><br>• Choice of vital signs to be monitored<br>• Deriving User Specifications<br>• Deriving Product Specifications<br>• Derive the enabling technologies for the product | | | |

# WORK PACKAGE 2 (2/4)

**Activities:**

- Analysis of the car application market and derivation of user specifications
- Development of product specifications
  - Vital sign detection study
  - Analysis of user specifications and derivation of product specifications
  - Analysis of product specifications and derivation of required enabling technologies
- Analysis of enabling technologies and derivation of the best for the use case

# WORK PACKAGE 2 (3/4)

**Roles hours per Task:**

1. Analysis of the car application market and derivation of user specifications. (Month 3)
    - Expert scientist in Automotive field. Approx: 100 hours (0.6 man/month)

2. Development of product specifications (Month 3-4)
    - Medical Expert. Approx: 100 hours (0.6 man/month)
    - Embedded Systems Engineer. Approx: 100 hours (0.6 man/month)

3. Analysis of enabling technologies and derivation of the best for the use case (Month 4-5)
    - Researcher scientist in AI. Approx: 100 hours (0.6 man/month)
    - Researcher scientis in Embedded systems. Approx: 100 hours (0.6 man/month)

# WORK PACKAGE 2 (4/4)

**Costs:**

- Researcher scientist in Automotive field. Approx: 100 hours (0.6 man/month)
  - €20 per hour x 100 hours = €2.000
- Medical Expert. Approx: 100 hours (0.6 man/month)
  - €20 per hour x 100 hours = €2.000
- Embedded Systems Engineer. Approx: 100 hours (0.6 man/month)
  - €40 per hour x 100 hours = €4.000
- Researcher scientist in AI. Approx: 100 hours (0.6 man/month)
  - €20 per hour x 100 hours = €2.000
- Researcher scientist in Embedded systems. Approx: 100 hours (0.6 man/month)
  - €20 per hour x 100 hours = €2.000

**Total Cost: €12.000**

# WORK PACKAGE 3 (1/4)

| WP 3 | **WP Title:** Development of product architecture<br>**WP Type:** R.I. | **Activity Start:** Month 6 | **Activity End:** Month 8 |
|---|---|---|---|
| **Man/Month:** 0.25 + 0.25 + 0.25 + 0.6 + 0.3 + 0.3 + 0.25 + 0.25 + 0.25 = 2.7 Man/Month | | | |
| **Objectives:**<br>• Product architecture development<br>• Identify specific Neural Network<br>• Identify Sensor Type | | | |

# WORK PACKAGE 3 (2/4)

**Activities:**

- Initial product architecture design
- Analysis and identification of the best neural network
- Analysis and identification of the best sensors for the use case
- Final product architecture design

# WORK PACKAGE 3 (3/4)

**Roles hours per Task:**

1. Initial product architecture design (Month 6)
    - Embedded Systems Engineer. Approx: 40 hours (0.25 man/month)
    - AI Engineer. Approx: 40 hours (0.25 man/month)
    - Biomedical Engineer. Approx: 40 hours (0.25 man/month)

2. Analysis and identification of the best neural network (Month 6-7)
    - AI Engineer. Approx: 100 hours (0.6 man/month)

3. Analysis and identification of the best sensors for the use case (Month 7-8)
    - Embedded Systems Engineer. Approx: 50 hours (0.3 man/month)
    - Biomedical Engineer. Approx: 50 hours (0.3 man/month)

4. Final product architecture design (Month 8)
    - Embedded Systems Engineer. Approx: 40 hours (0.25 man/month)
    - AI Engineer. Approx: 40 hours (0.25 man/month)
    - Biomedical Engineer. Approx: 40 hours (0.25 man/month)

# WORK PACKAGE 3 (4/4)

**Costs:**

- Embedded Systems Engineer. Approx: 120 hours (0.75 man/month)
  - €40 per hour x 40 hours = €1.600
  - €40 per hour x 50 hours = €2.000
  - €40 per hour x 40 hours = €1.600

- AI Engineer. Approx: 120 hours (0.75 man/month)
  - €40 per hour x 40 hours = €1.600
  - €40 per hour x 100 hours = €4.000
  - €40 per hour x 40 hours = €1.600

- Biomedical Engineer. Approx: 80 hours (0.5 man/month)
  - €40 per hour x 40 hours = €1.600
  - €40 per hour x 50 hours = €2.000
  - €40 per hour x 40 hours = €1.600

**Total Cost: €17.600**

# WORK PACKAGE 4 (1/4)

| WP 3 | **WP Title:** Product development<br>**WP Type:** S.S. | **Activity Start:** Month 9 | **Activity End:** Month 12 |
|---|---|---|---|
| **Man/Month:** 0.6 + 0.9 + 0.9 + 0.9 = 3.3 Man/Month | | | |
| **Objectives:**<br>• Neural network development<br>• Embedded software development<br>• Prototype development and testing | | | |

# WORK PACKAGE 4 (2/4)

**Activities:**

- Development of the neural network that classifies the data collected by the sensor
  - Development and Training of the network
  - Testing and evaluation of the network

- Development of embedded software
  - Development of the controller firmware
  - Development of the sensor driver
  - Driver testing

- Development of the prototype
  - Testing and evaluation of the prototype

# WORK PACKAGE 4 (3/4)

**Roles hours per Task:**

1. Development of the neural network that classifies the data collected by the sensor (Month 9)
   - AI Engineer. Approx: 100 hours (0.6 man/month)

2. Development of embedded software (Month 9-10)
   - Embedded Systems engineer. Approx: 150 hours (0.9 man/month)

3. Development of the prototype (Month 11-12)
   - AI Engineer. Approx: 150 hours (0.9 man/month)
   - Embedded Systems engineer. Approx: 150 hours (0.9 man/month)

# WORK PACKAGE 4 (4/4)

**Costs:**

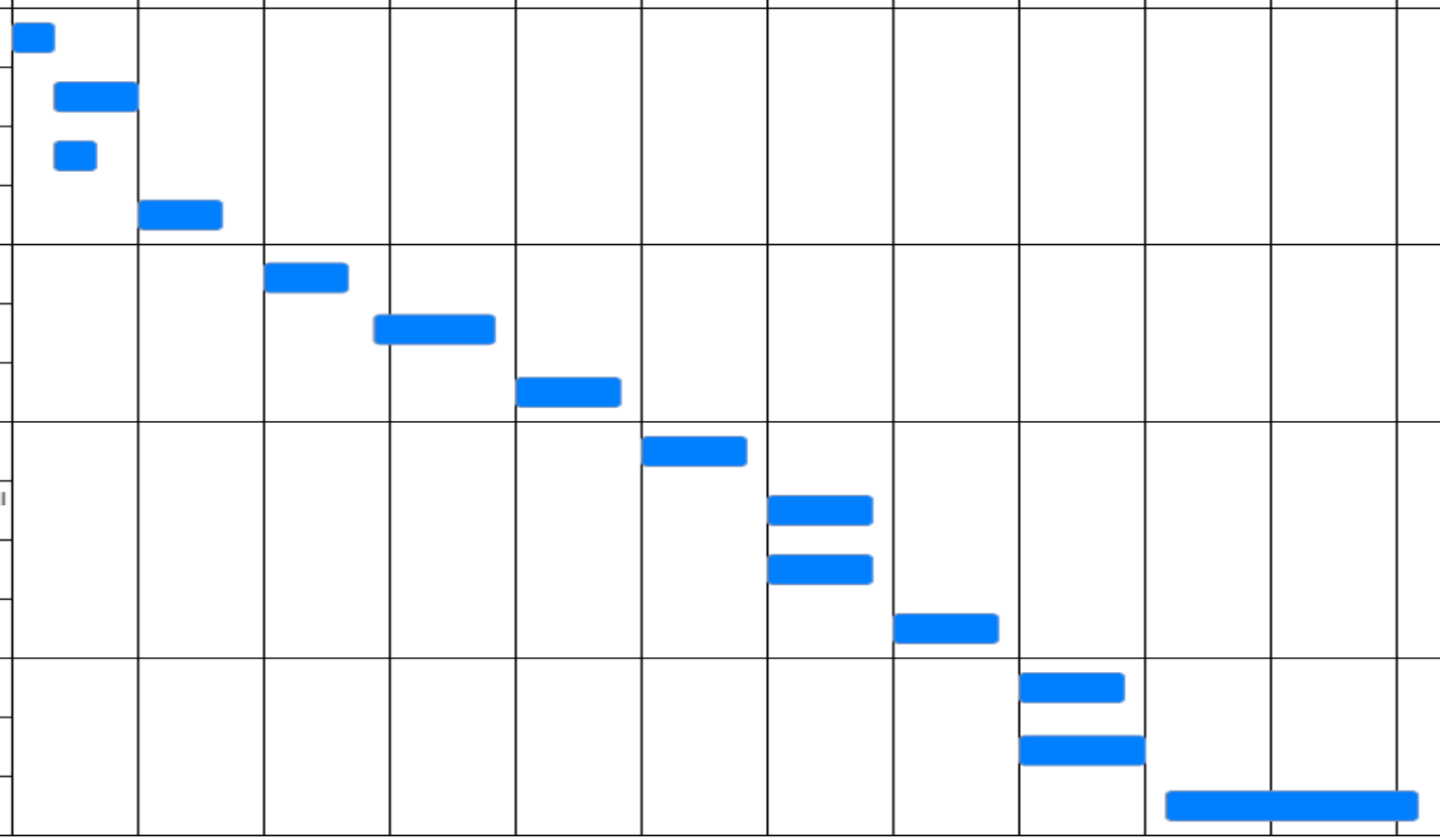
- AI Engineer. Approx: 250 hours (1.5 man/month)
  - €40 per hour x 100 hours = €4.000
  - €40 per hour x 150 hours = €6.000

- Embedded Systems Engineer. Approx: 300 hours (1.8 man/month)
  - €40 per hour x 150 hours = €6000
  - €40 per hour x 150 hours = €6000

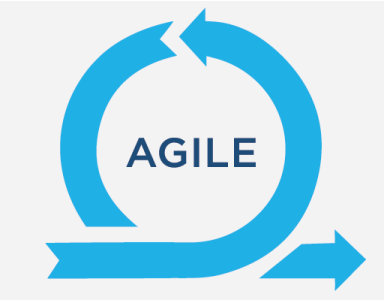
**Total Cost: €22.000**

# GAANT CHART

| PACKAGE | ACTIVITY | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10 | M11 | M12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WP1 | Analysis of the accident causes | | | | | | | | | | | | |
| | Market analysis | | | | | | | | | | | | |
| | Analysis of the accident rates | | | | | | | | | | | | |
| | Study of monitoring technologies | | | | | | | | | | | | |
| WP2 | User Specifications | | | | | | | | | | | | |
| | Product Specifications | | | | | | | | | | | | |
| | Enabling Technologies | | | | | | | | | | | | |
| WP3 | Initial architecture | | | | | | | | | | | | |
| | Analysis of the neural network | | | | | | | | | | | | |
| | Alalysis of the best sensors | | | | | | | | | | | | |
| | Final architecture | | | | | | | | | | | | |
| WP4 | Development of the neural network | | | | | | | | | | | | |
| | Development of the embedded software | | | | | | | | | | | | |
| | Development of the prototype | | | | | | | | | | | | |



# RISK ANALYSIS (1/2)




**INTERNAL RISKS:**

- **Errors and Delays during project development**

Errors and possible delays can result in increased project costs.
Delays were minimized by trying to allocate a congruous number of hours for each task.
Errors are minimized by using the **AGILE** methodology, which allows efficient error correction due to its multiple iterations.

- **Enabling Technologies not found**

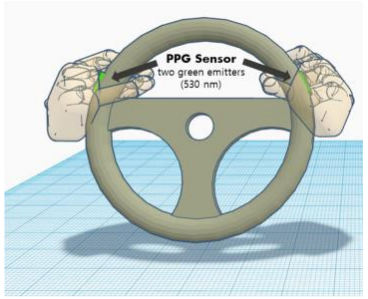
If the chosen enabling technologies cannot be found, it will be sufficient to replace them with similar technologies due to the modularity of the system.
For example, in the absence of suitable ppg sensors we could choose another sensor from which can be extracted hearth rate variability (HVR).

# RISK ANALYSIS (2/2)

**EXTERNAL RISKS:**

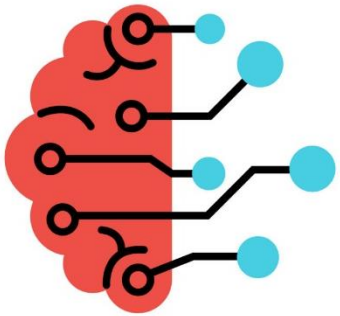
- **PPG Sensor**

The data collected is used to extract the Herath rate variability (HRV), which can be extracted from many other types of sensors.
Therefore, if the PPG sensor fails in the market, it would not be a problem, since another sensor would be fine to extract this feature.




- **LSTM Neural Network**

We chose the LSTM neural network because it is currently the best solution in long time-series classifications.
If, in the future, a better solution will be discovered, the network can be replaced, since the system depends on the classification and not on the type of network chosen.

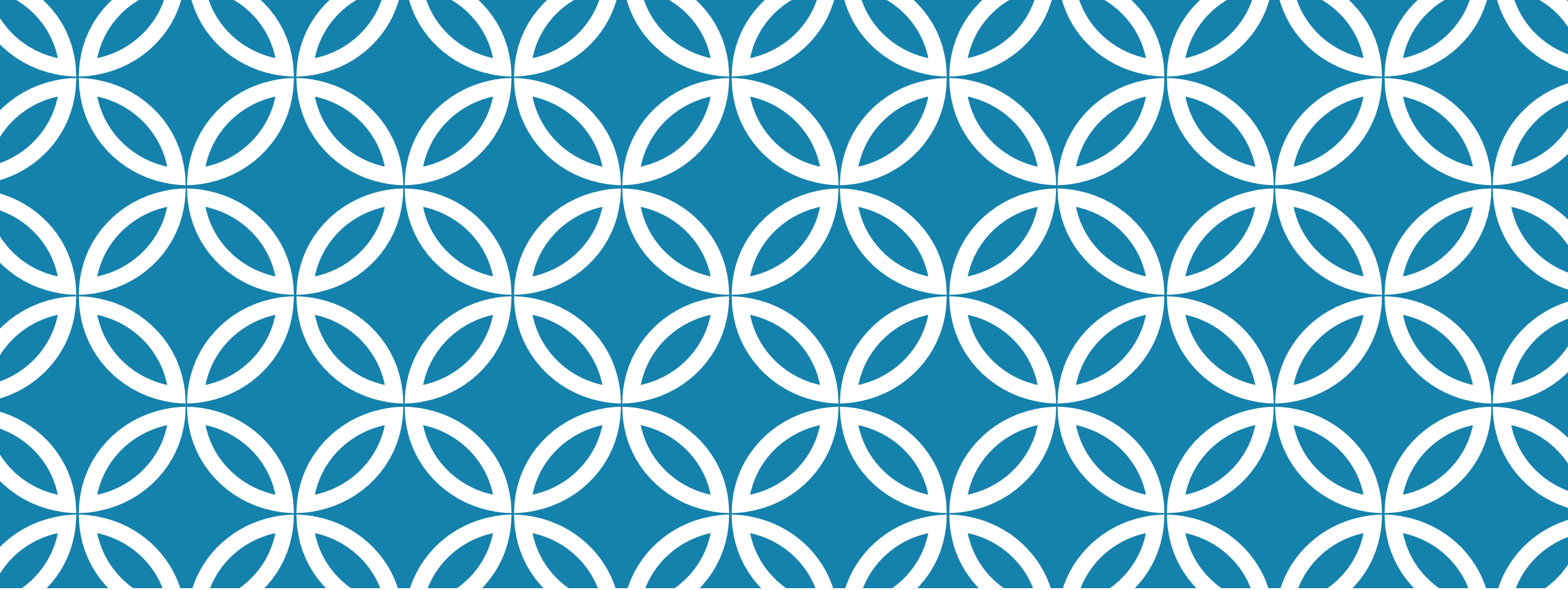


# REFERENCES (1/2)


- **Syncope via PPG and ECG:** https://pubmed.ncbi.nlm.nih.gov/25769176/
- **Seizure via PPG and ECG:** https://www.mdpi.com/1424-8220/21/18/6017
- **Hypoglycemia via PPG:** https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10057625/
- **Hearth attack via PPG:** https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9371833/
- **Stroke via PPG and ECG:** https://ieeexplore.ieee.org/document/9761215
- **Hypoglicemia via ECG:** https://journals.sagepub.com/doi/10.1177/19322968221116393
- **Heart attack via ECG:** https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6632021/
- **Seizure from IR Camera:** https://www.seizsafe.com/en/

# REFERENCES (2/2)


- **Man/Month info:** 160 (40 hours per week-full time job)
- **Cost Researcher:** https://www.unipi.it/index.php/phoca-prova/category/84-docenti-tabelle-retributive?download=6462:2022-costo-annuo-lordo-personale-dei-professori-e-ricercatori-universitari-secondo-il-nuovo-regime-art-3-comma-2-e-6-del-d-p-r-15-12-2011-n-232-adeguamento-stipendiale-aumento-0-45-dpcm-25-luglio-2022
- **Cost Embedded Systems Engingeer:** https://www.upwork.com/hire/embedded-systems-engineers/cost/
- **Cost Medical Expert**: https://www.becomeopedia.com/medical-researcher/



# THANKS FOR THE ATTENTION

Federico Cavedoni
Francesco Bruno