Understanding Human Movement

Advanced inertial sensors data processing for recognizing human activities and characterizing movements

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   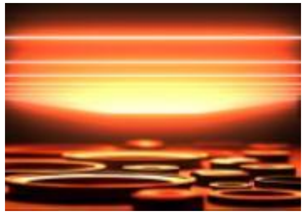 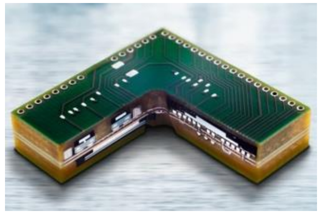   

- Innovation Research
- Information and Communication Technology
- Life Sciences
- Light & Surfaces
- Microelectronics
- Production
- Defense and Security
- Materials and Components

72 Institutes

> 80 Research Units

~ 25,000 Employees

> € 2.3 billion R&D Budget
(€ 2 billion contract research)

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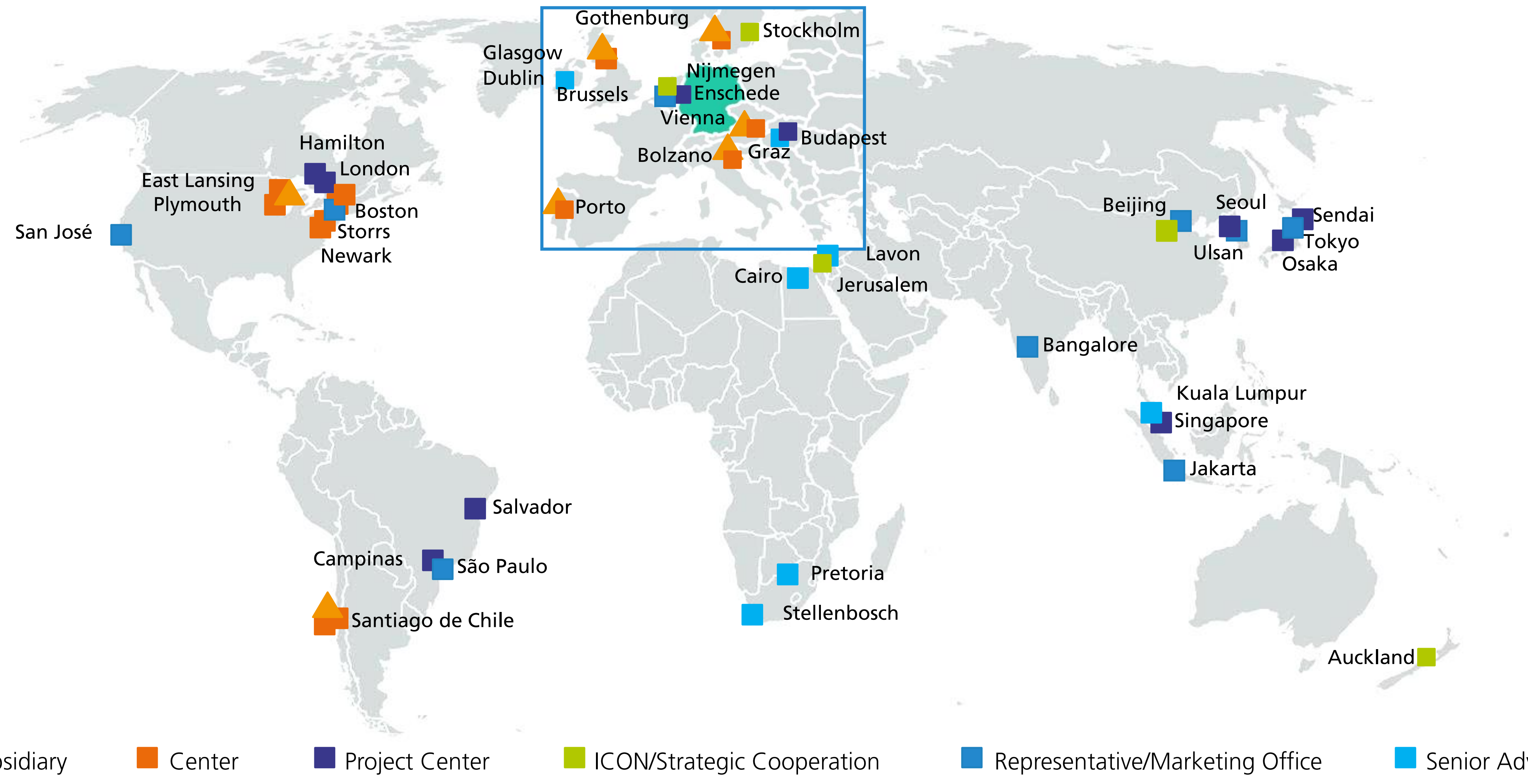

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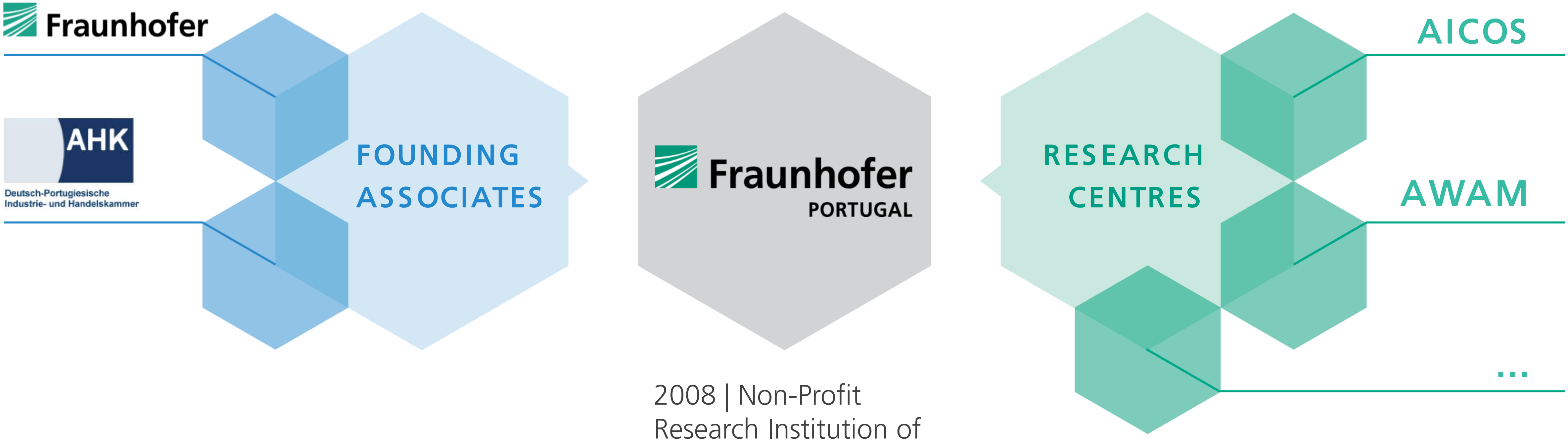
Institutional Background

ASSOCIAÇÃO FRAUNHOFER PORTUGAL RESEARCH



2008 | Non-Profit
Research Institution of
Public Common Interest

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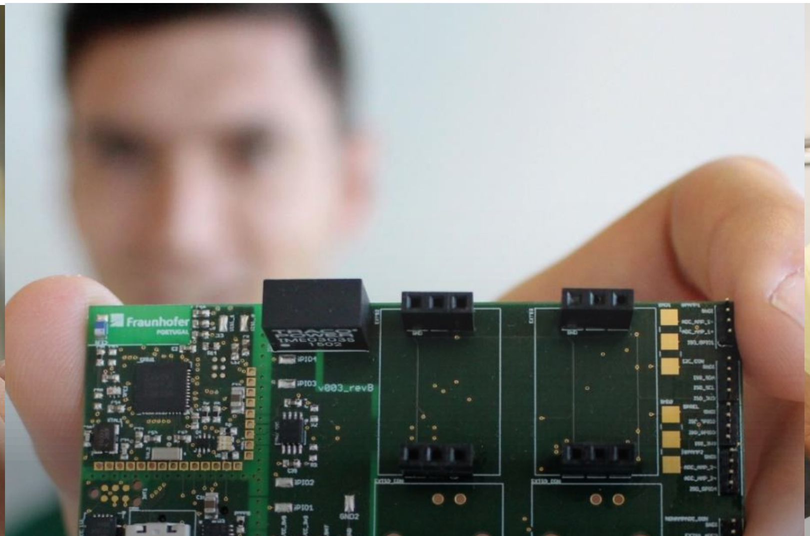
Purpose and Scientific Areas

INTELLIGENT SYSTEMS

- Edge and Cloud Computer Vision
- Sensor Fusion & Embedded Intelligence
- Cognitive Systems & Deep Learning
- Predictive Modelling & Recommendation



CONNECTED THINGS

- Embedded Electronics
- Communication and Networks
- Edge and Cloud Computing
- Quality Assurance & Regulatory Pre-Compliance

HUMAN-CENTRED DESIGN

- Understanding people in diverse settings
- Co-designing meaningful technologies
- Technology assessment in real life

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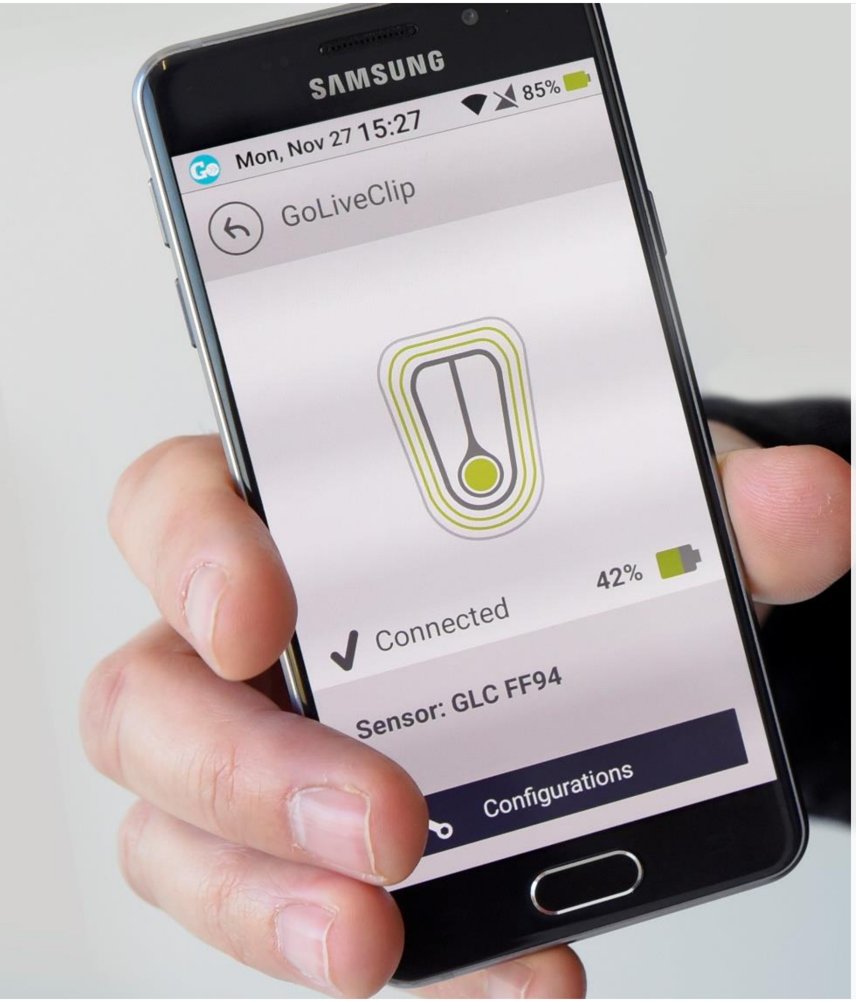
Purpose and Scientific Areas



ASSISTIVE INFORMATION AND COMMUNICATION SOLUTIONS

Relying on data and treating it intelligently to unveil hidden patterns and support decisions

INTELLIGENT SYSTEMS

- Edge and Cloud Computer Vision
- Sensor Fusion & Embedded Intelligence
- Cognitive Systems & Deep Learning
- Predictive Modelling & Recommendation

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Understanding Human Movement

MOTION

Advanced inertial sensors data processing for recognizing human activities and characterizing movements

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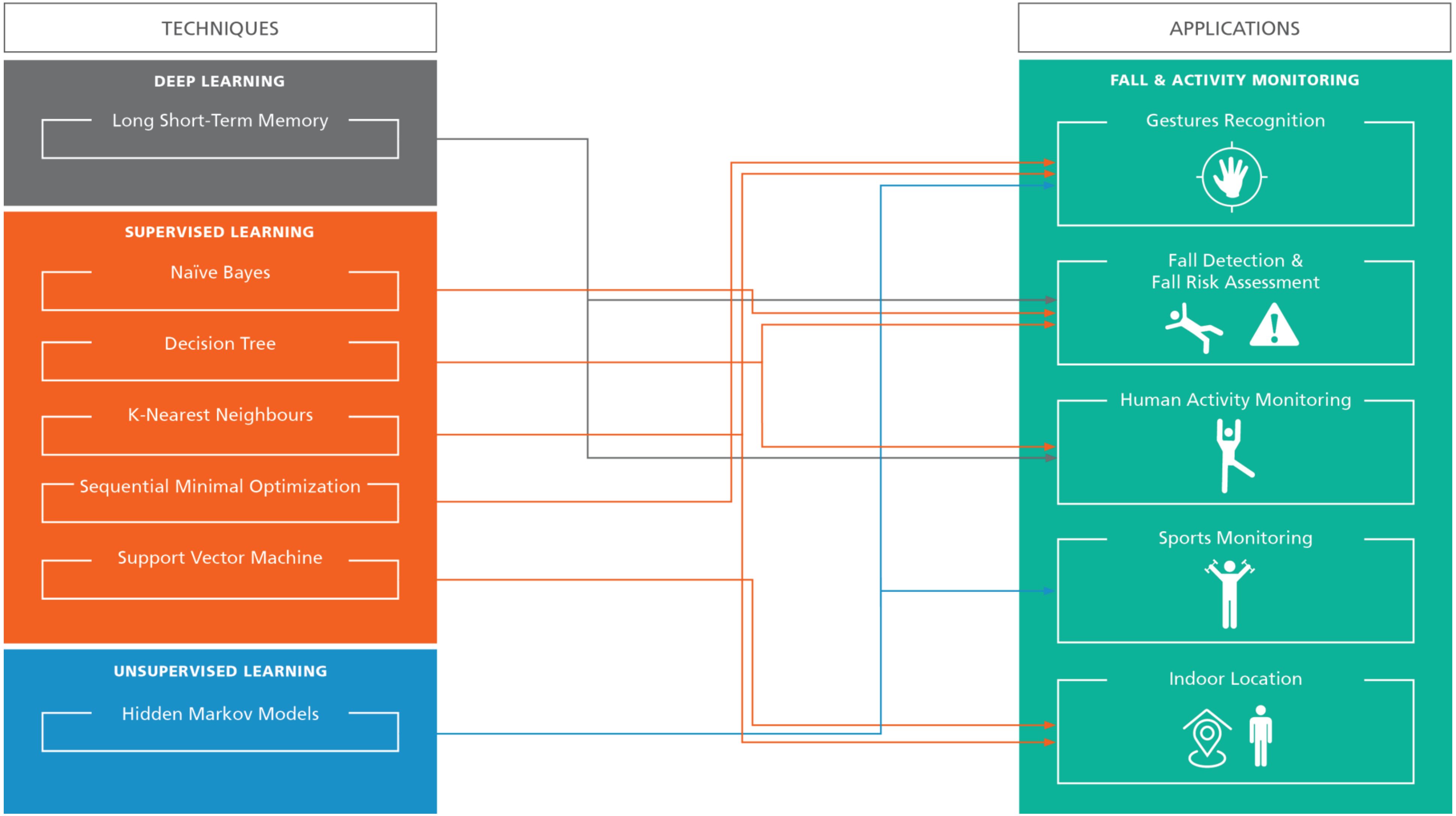
Machine Learning for Time Series



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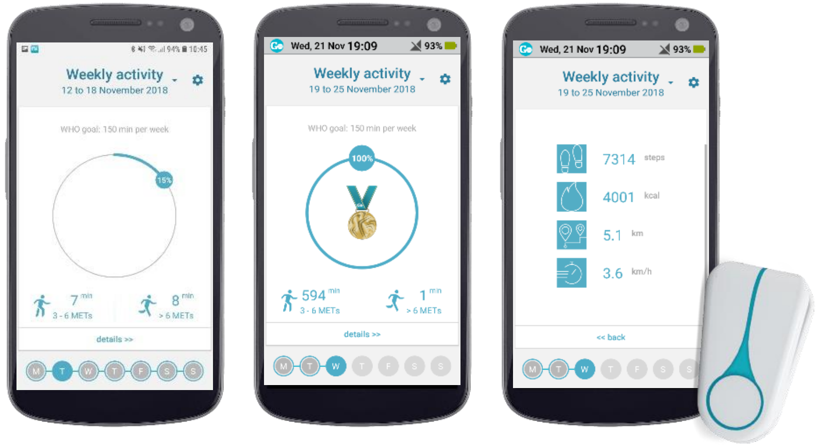
Fraunhofer AICOS background work

Human Motion since 2009

MOVER

ACTIVITY MONITORING

(Silva et al., 2014; Aguiar et al., 2014; Carneiro et al., 2015; Figueira et al. 2016; Pereira et al. 2018)



2009

2019

(Aguiar et al., 2014; Vermeulen et al., 2015; Silva et al., 2018)

FALL DETECTION

(Guimarães et al., 2014, Silva et al, 2016)

FALL RISK ASSESSMENT

Algorithm	Accuracy
Step detection	96.6%
Distance estimation	88.8%
Physical activity classification	99.5%
Fall detection	97.0%

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Human Activity Recognition

Contextualization

- Tracking of daily activities pervasively

- Perceive and self-reflect about daily physical activities
- Reducing the risk of health problems

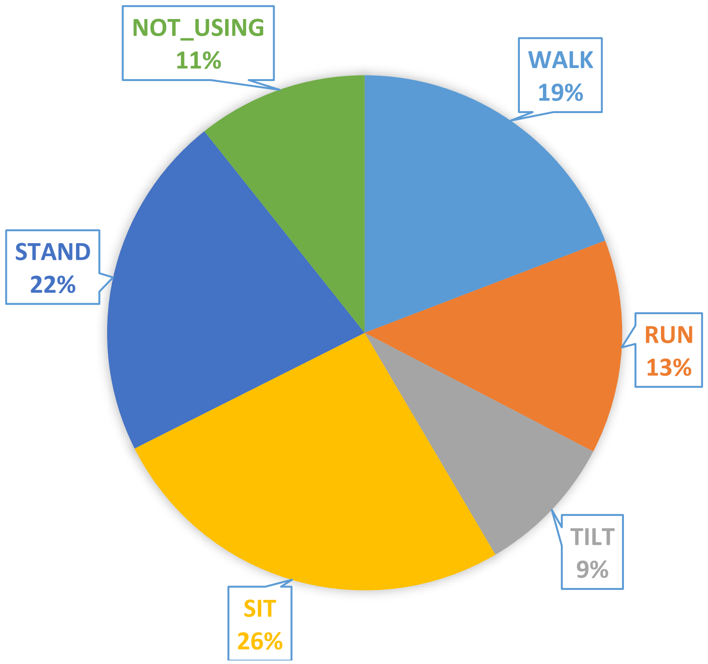
- Smartphone or wearable based solutions:
  - Inertial sensors
  - Pervasive solution
  - Automatic tracking
  - Visualization interface

Human Activity Recognition

Daily Activities

- Dataset
  - Number of classes: 7
    - Walking, Running, Tilting, Standing, Sitting, Lying, Not Using
  - Size: 117 hours of human activity data
  - Type: 3D accelerometer
  - Wearable on chest, pocket, belt, and wrist

- Decision Tree classifier
  - Number of features: 8
    - Low computational statistical features

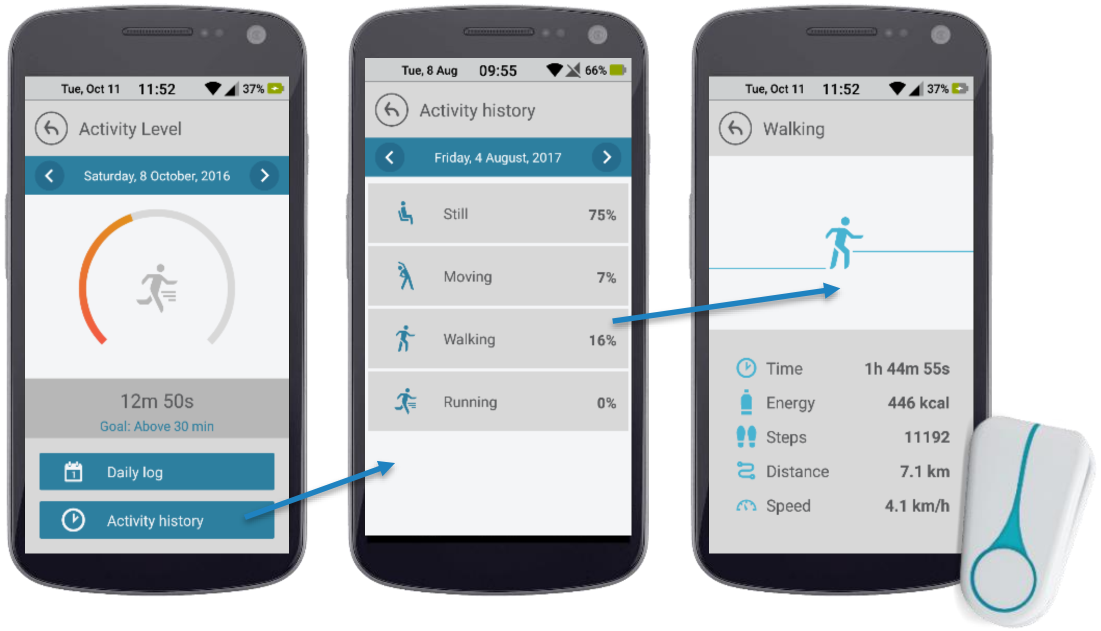


Human Activity Recognition

Daily Activities

- Results
  - Validation: 10-folds cross validation
  - Train: 70%
  - Test: 30%
  - Accuracy: 93.4%

Activity	Hours of data	Recall (%)	Precision (%)
Walk	16	90.8	96.2
Run	9	95.4	86.0
Tilt	8	91.1	53.6
Stand + Still	32	91.4	99.4
Not using	13	93.6	88.6



B. Aguiar, J. Silva, T. Rocha, S. Carneiro and I. Sousa, "Monitoring physical activity and energy expenditure with smartphones," IEEE-EMBS BHI, Valencia, 2014, pp. 664-667.
S. Carneiro *et al.*, "Accelerometer-based methods for energy expenditure using the smartphone," in MeMeA, 2015, pp. 151–156.

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Human Activity Recognition

Physical Activities Intensity

- Dataset
  - Number of classes: 4
    - Sedentary, Light, Moderate and Vigorous
  - Size: 41 hours
  - Type: 3D accelerometer
    - Badge on the neck (loosen), clipped to the uniform on the chest, inside the trousers pocket and clipped to the trousers pocket
- Decision Tree classifier
  - Number of features: 12
  - Foward Feature Selection

Activity	Activity Level
Laying on bed	Sedentary
Sitting (not moving)	Sedentary
Standing (not moving)	Sedentary
Organizing material on shelves	Light
Cleaning table	Light
Cleaning small object (smartphone)	Light
Typing on a computer	Light
Walking (free) on different directions	Moderate
Pushing person on wheelchair	Moderate
Walking on treadmill (4.5 km/h)	Moderate
Descending stairs	Moderate
Mopping floor	Moderate
Running on treadmill (6.5-8 km/h)	Vigorous
Climbing stairs (fast pace)	Vigorous

Pereira, A., Nunes, F., & AICOS, F. P. (2018). Physical Activity Intensity Monitoring of Hospital Workers using a Wearable Sensor. *Proc. of PervasiveHealth*, *18*.

Human Activity Recognition

Physical Activities Intensity

- Results
  - Feature Selection: 2
  - Validation: leave one out user cross validation
  - Train: 15 subjects
  - Test: 5 subjects
  - Accuracy: 83.2 ± 6.8 %

	Sedentary	Light	Moderate	Vigorous	Sensibility (%)
Sedentary	978	69	0	0	93,41
Light	346	602	17	0	62,38
Moderate	0	159	831	3	83,69
Vigorous	0	0	4	552	99,28
Specificity (%)	86,24	91,22	99,18	99,90	

Pereira, A., Nunes, F., & AICOS, F. P. (2018). Physical Activity Intensity Monitoring of Hospital Workers using a Wearable Sensor. *Proc. of PervasiveHealth, 18.*

Anomaly Detection

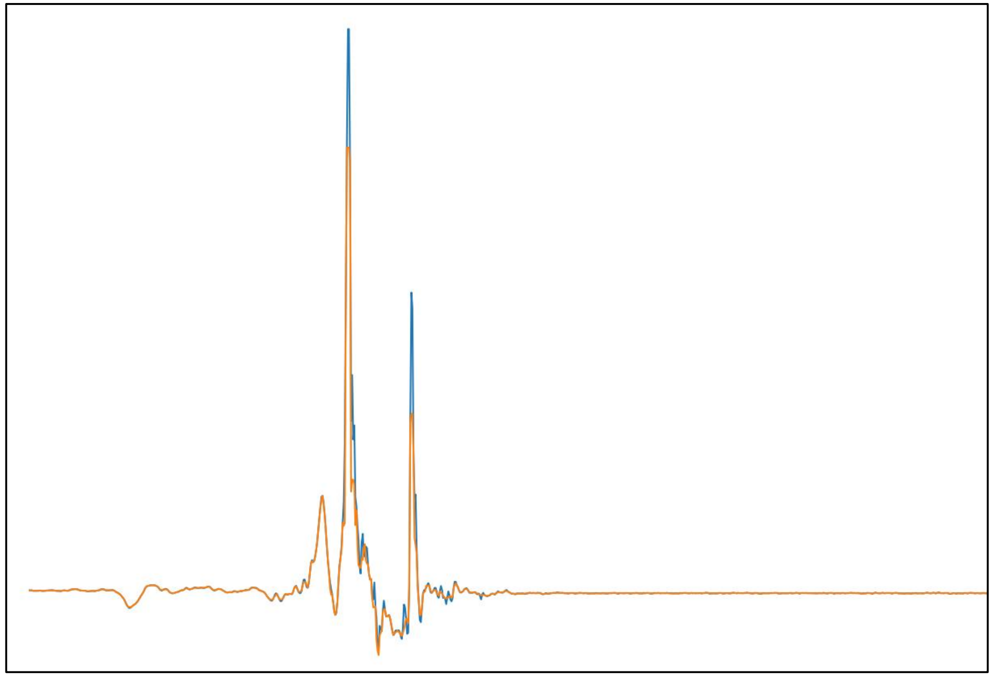
Contextualization

- An anomaly is an unexpected phenomena which differs significantly from the majority of data
- Anomalies are often associated with unwanted events
- Unbalanced problem
- Applications examples range from medical and public health to industrial environments:
  - Fall detection
  - Production line on idle
  - Musculosketical disorders prevention

Anomaly Detection

Wrist Fall detection

- Training dataset
  - Number of classes: 2
    - Fall: 1235 samples
    - Non Fall: 1574 samples
- Validation set: 18 hours
  - 108 falls
- Type: 3D – Accelerometer
  - Wearable on the wrist



Accelerometer magnitude of a fall event, with the wearable in the wrist.

- Decision Tree
  - Number of features: 15
  - Low computational statistical features

Anomaly Detection

Wrist Fall detection

- Training results
  - Features selected: 4
  - Test with 30% of data
  - Sensitivity: 86.4%
  - Specificity: 98.7%

- Validation results
  - 1 FP during 18h
  - Sensitivity: 84.3%

Validation Results

Sensitivity	84.3 %
Precision	98.9 %
F1-Score	91.0 %
Detected falls	91 / 108
False alarms	1 / 18h
False alarms per hour	0.06
False alarms per day (16.5 hours of usage)	0.92

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Machine Learning for Time Series

- Multiple source signal acquisition

- Sampling Frequency and Time Complexity Analysis
- Feature Extraction and Selection

- Classification Algorithms

- Accuracy
- Confusion Matrix

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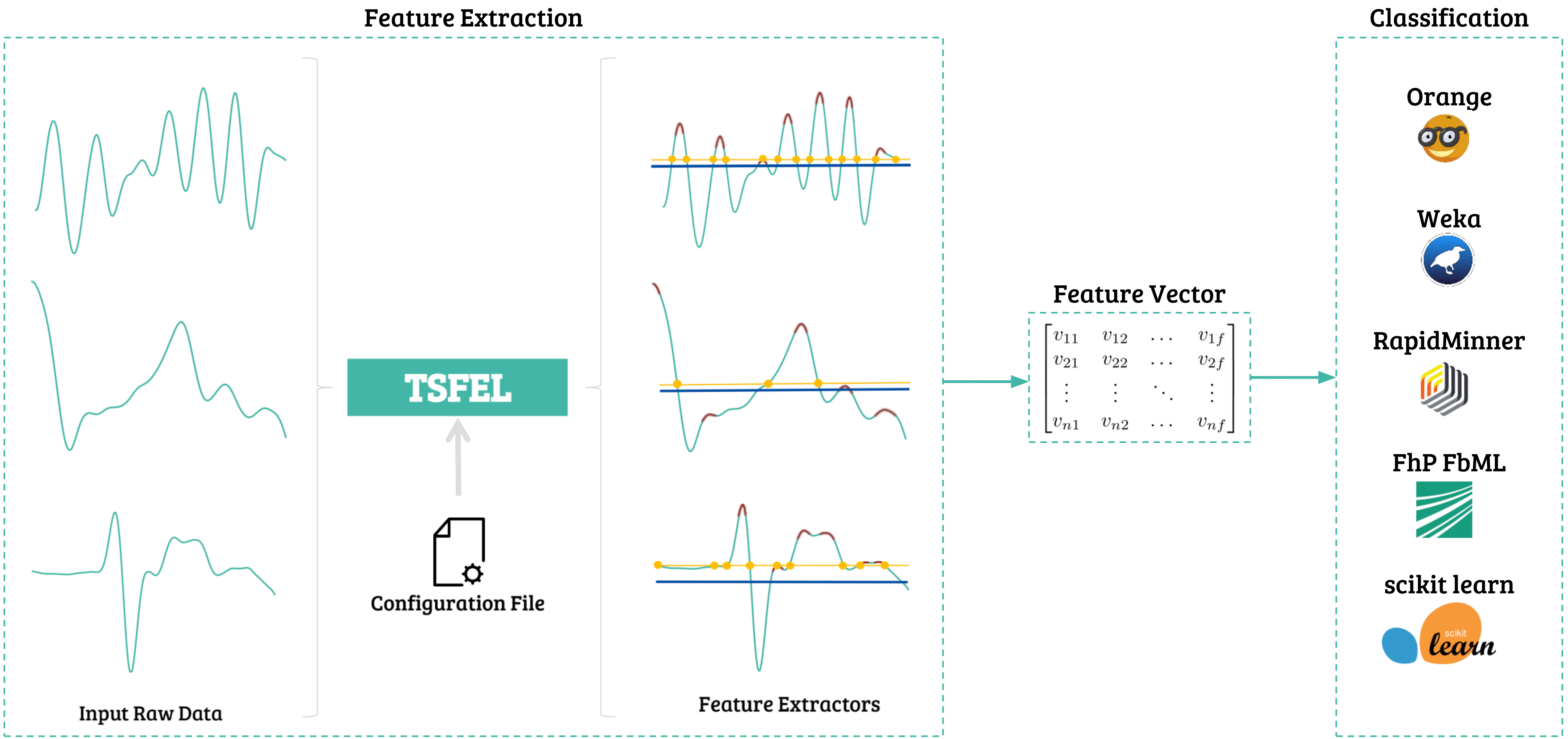
TSFEL: Time Series Feature Extraction Library



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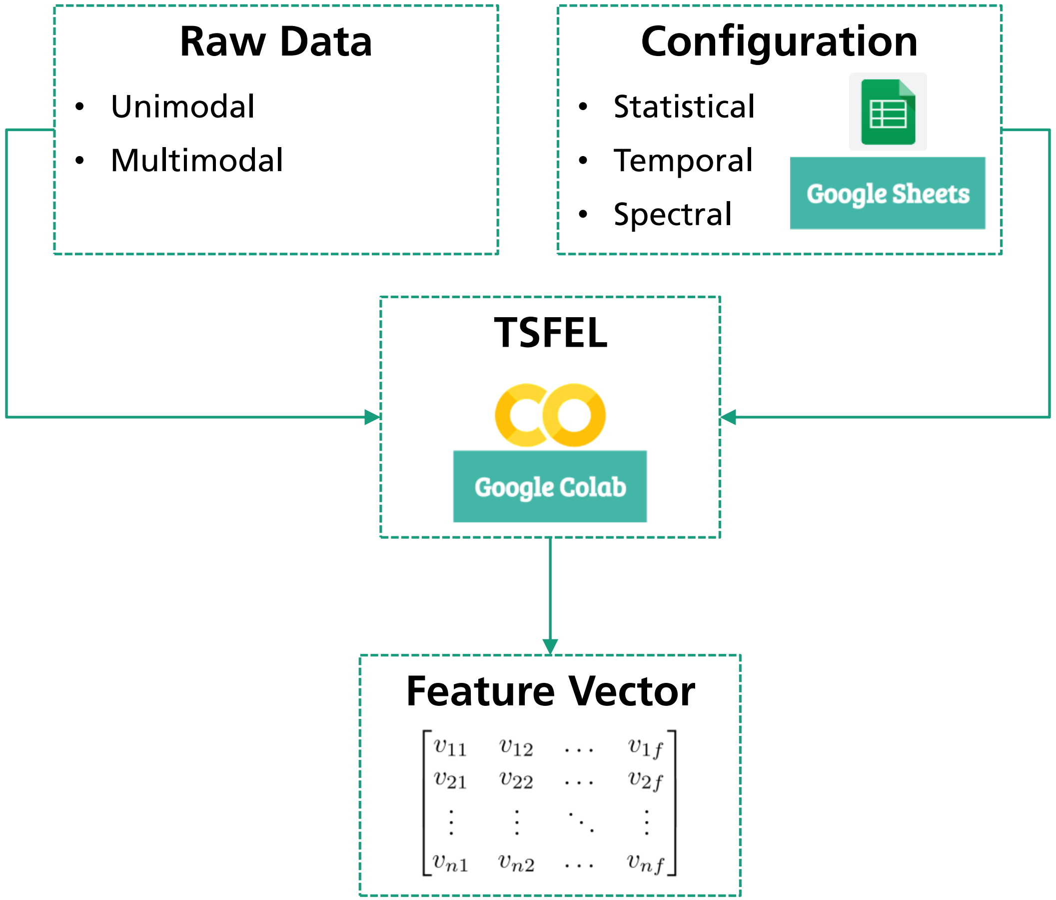
TSFEL: Time Series Feature Extraction Library

- Assists researchers on **initial exploratory data analysis** tasks without significant programming effort

- **Google Colab** and **Google Sheets** provide high-level abstraction.



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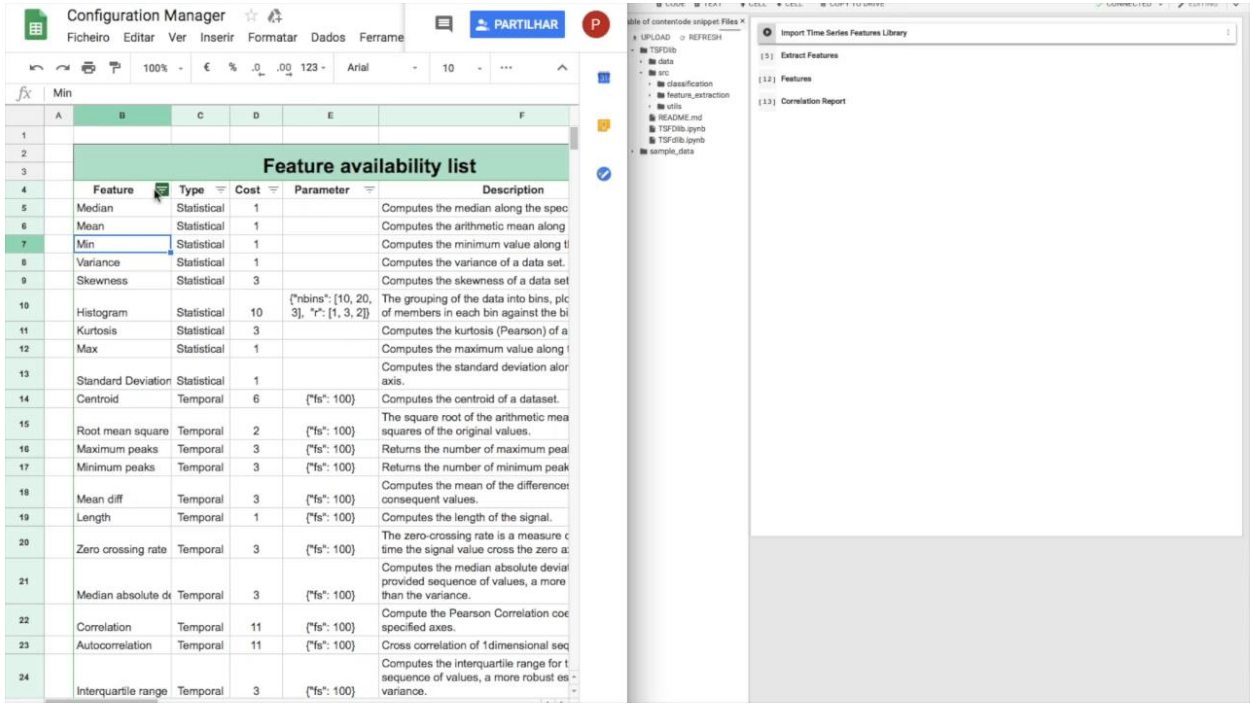
TSFEL: Time Series Feature Extraction Library

Intuitive, fast deployment and reproducible

Interactive UI for feature selection and customization



Computational complexity evaluation

Know the computational effort before extracting features

Comprehensive documentation

Each feature extraction method has a detailed explanation

Unit Tested

Unit tests are provided for each feature

Easily extended

Adding new features is easily achieved using a JSON format

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SmartCompanion App

Demonstration

Award-winning Applications

- Smart Companion includes applications that have won the recognition from Google, Vodafone, World Summit Award Mobile and Zon.

Visit the website

http://smartcompanion.projects.fraunhofer.pt/

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References


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PORTUGAL
RESEARCH CENTER FOR ASSISTIVE INFORMATION AND COMMUNICATION SOLUTIONS
sensor fusion
computer vision
Machine Learning @ Fraunhofer Portugal AICOS

White paper: Machine Learning @ Fraunhofer Portugal AICOS, May 2017

- Joana Silva, Carina Figueira, Marília Barandas, João Gonçalves, João Costa, Luís Rosado, Maria Vasconcelos, Filipe Soares and Hugo Gamboa

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