DEVELOPMENT OF SMART MULTI-SENSORY SOLUTIONS FOR THE ACTIVE AGEING AND WELL BEING

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Ph.D. Brainstorming Day

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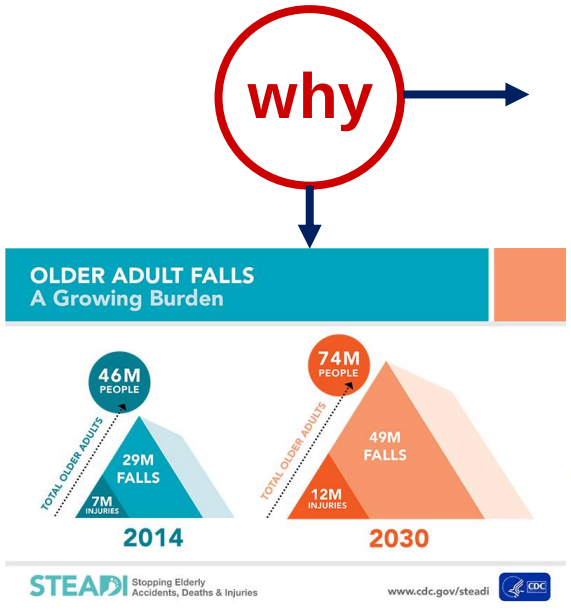
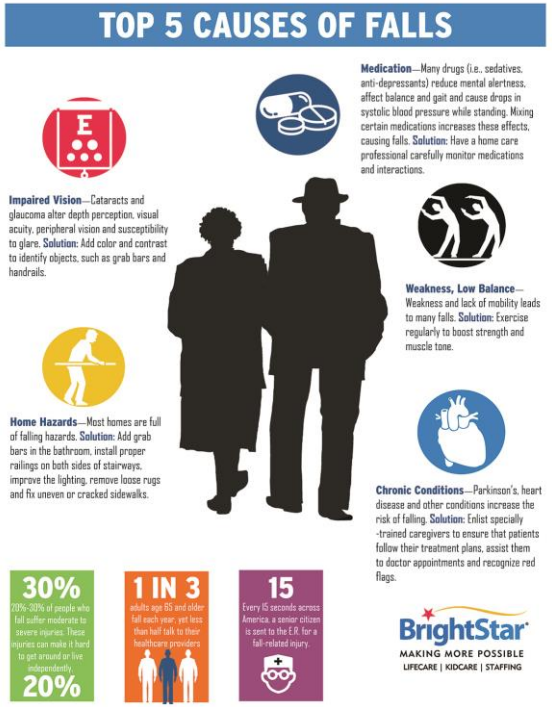
Research Topics

Development of smart multi-sensor solution in the framework of assistive technology

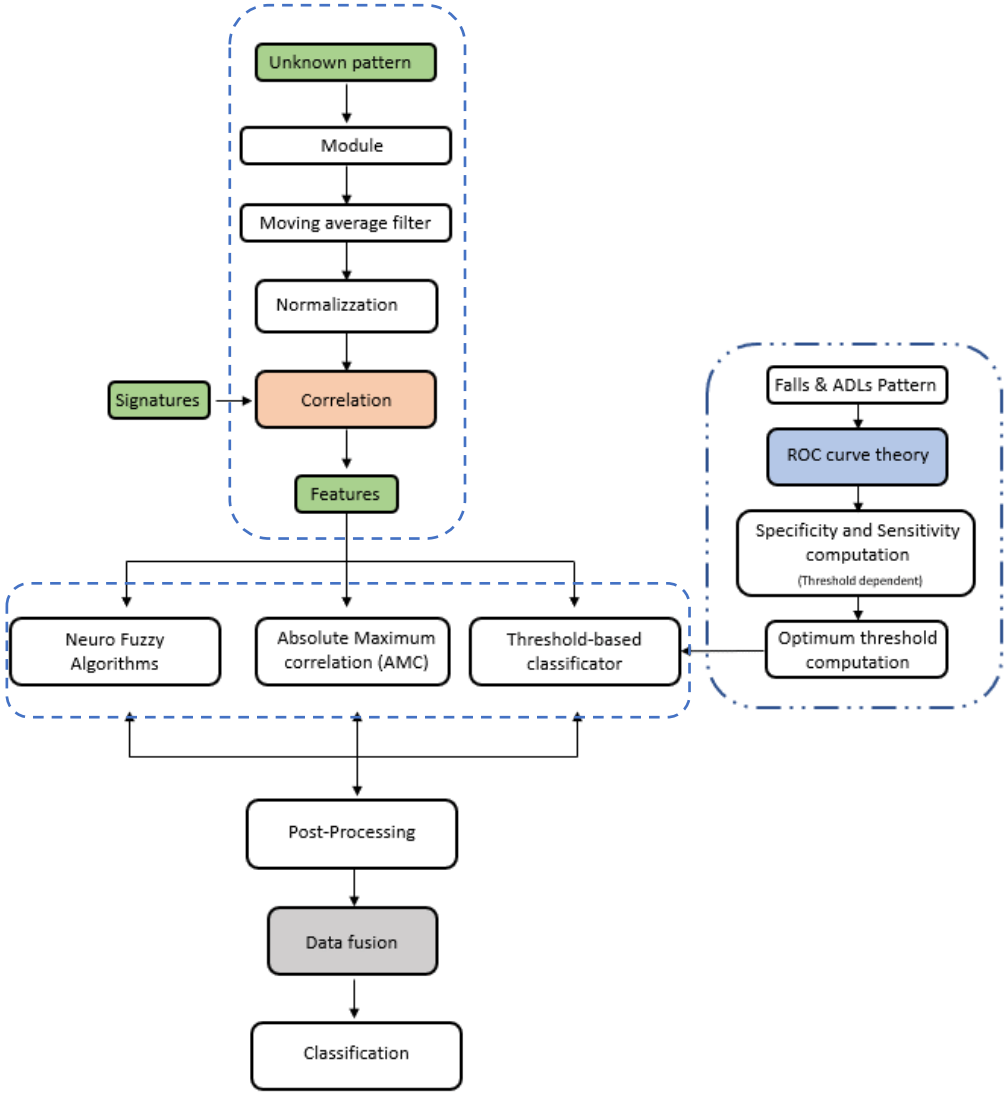
- Fall detection and classification
- Postural instability (primary cause for falls)
- Assisted diagnosis system in neurological context
- Navigation aids

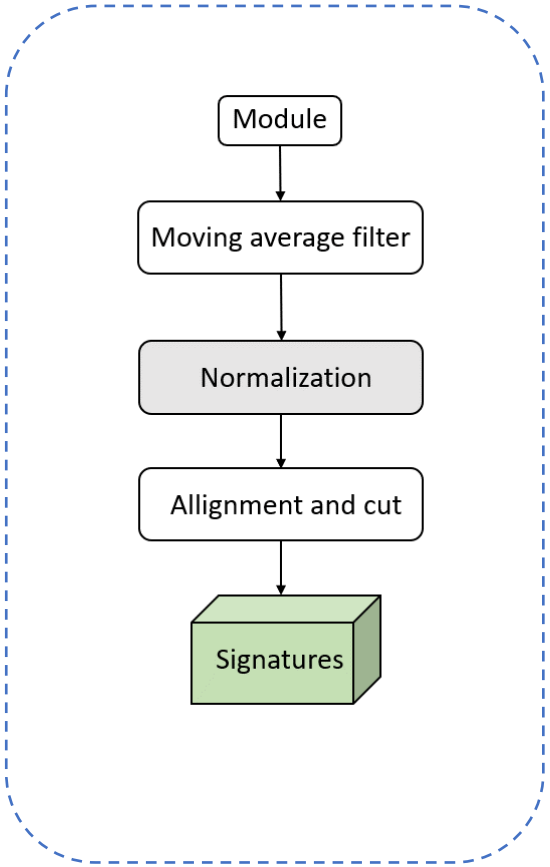




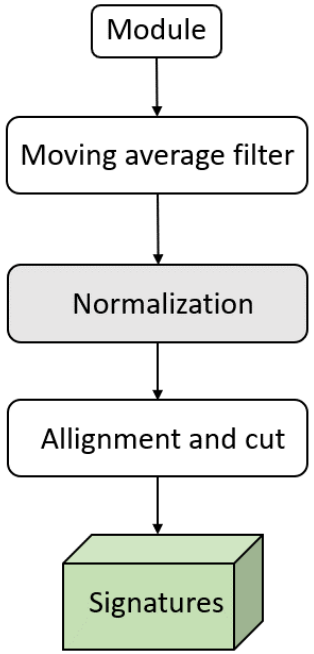
Fall Detection

General Methodology

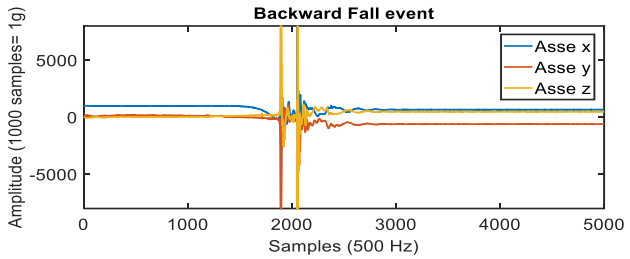


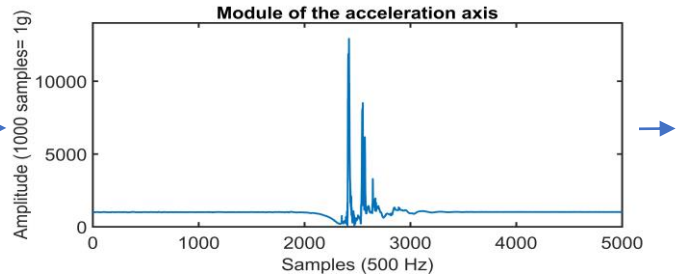


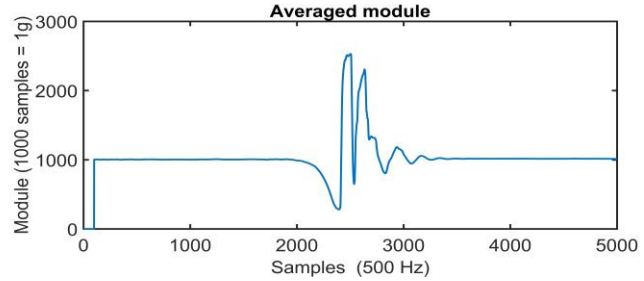
Fall Detection

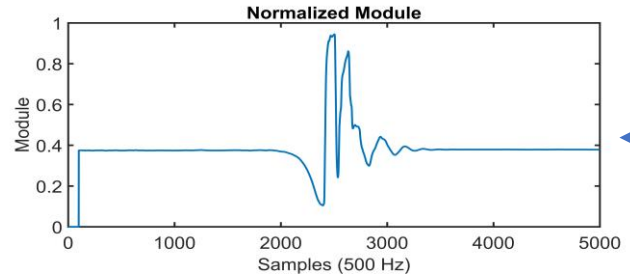


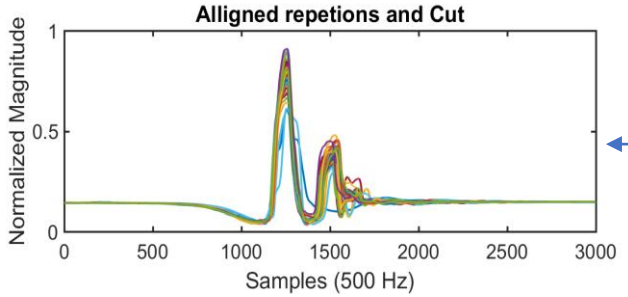
Signature Generation

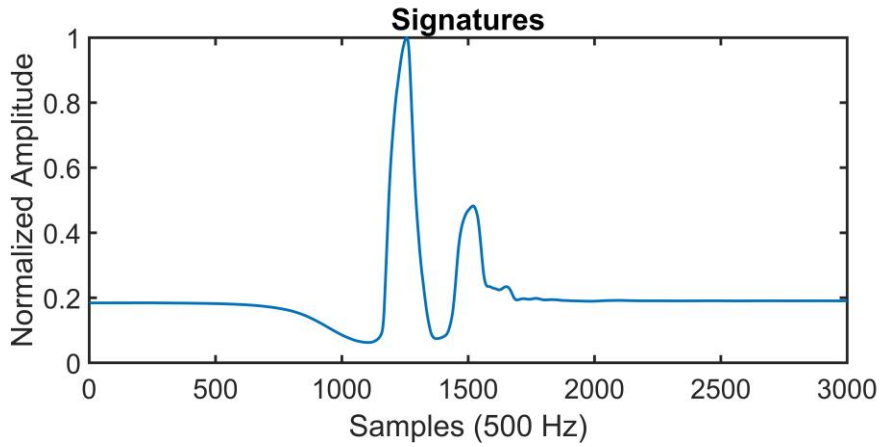












Dataset:

- **Fs= 500 Hz**
- **Acquisition duration: 10 s**
- **Repetitions: 10**
- **Users: 5**

Moving average filter:

- **Time window: 100 samples (200 ms)**
- **Shift: 1 sample (2 ms)**

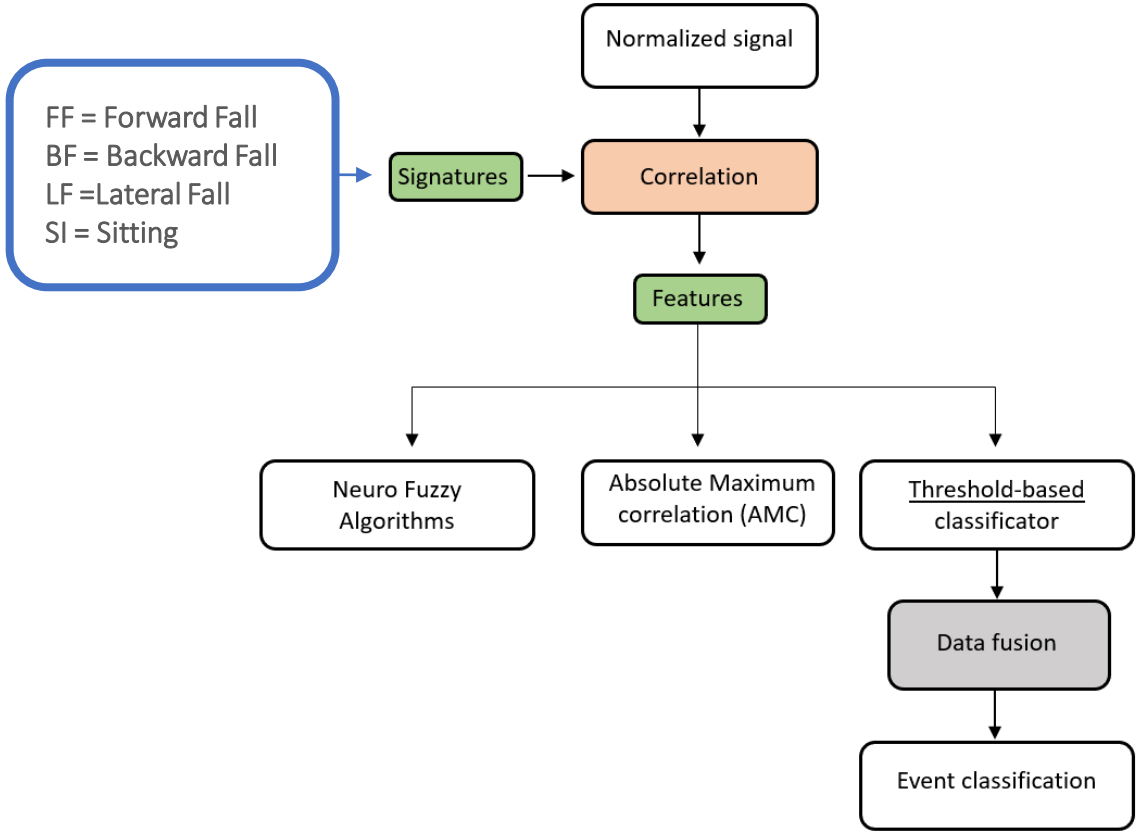
Normalization:

- **Every signal is normalized as respect the absolute maximum and minimum**

Fall Detection

Correlation Phase

Features: correlation's maximum value between the unknown event and the signature



10 Forward Falls (FF)

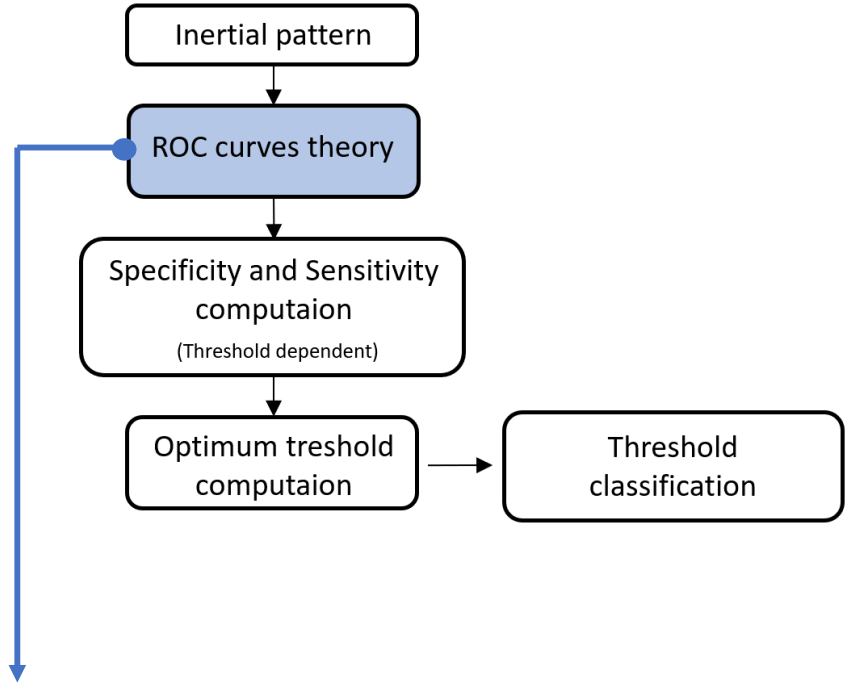
FF	BF	LF	SI
0.9447	0.7318	0.7195	0.7043
0.8225	0.942	0.7585	0.7585
0.4387	0.9296	0.5806	0.6925
0.7013	0.9563	0.7083	0.7494
0.9564	0.7188	0.7336	0.672
0.9028	0.3757	0.58	0.4524
0.9431	0.4865	0.6759	0.4685
0.9346	0.5353	0.6278	0.6146
0.9422	0.6452	0.7149	0.5741
0.8465	0.9086	0.7487	0.7468

Low Cross-correlation

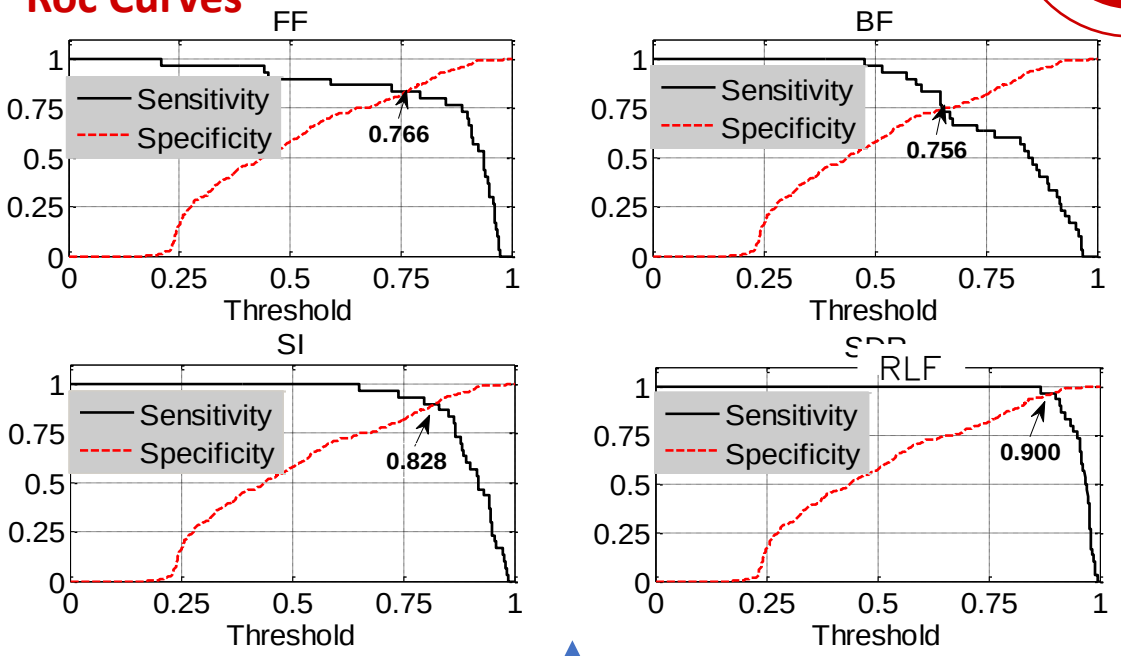
High Cross-correlation

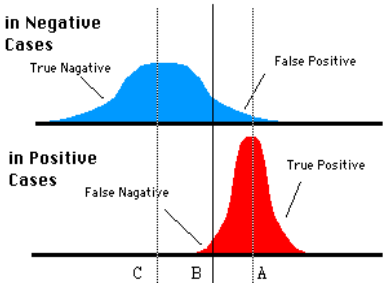
Very high Cross-correlation

Fall Detection



Roc Curves





FP = False Positives
FN = False Negatives
TP = True Positives
TN = True Negatives

$$Specificity = \frac{TN}{TN + FP}$$

It evaluates the algorithm performance on **evaluating, in a specific way, the type of event.**

$$Sensitivity = \frac{TP}{TP + FN}$$

It evaluated the algorithm performance on **detecting an event.**

Fall Detection

Classification Results

10 Forward Falls (FF)

FF	BF	LF	SI
0.9447	0.7318	0.7195	0.7043
0.8225	0.942	0.7585	0.7585
0.4387	0.9296	0.5806	0.6925
0.7013	0.9563	0.7083	0.7494
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0.9422	0.6452	0.7149	0.5741
0.8465	0.9086	0.7487	0.7468

Threshold values computed by means of the ROC curves theory

0.7664	0.7555	0.8155	0.8282

10 Classified Forward Falls

FF	BF	LF	SI
1	0	0	0
1	1	0	0
0	1	0	0
0	1	0	0
1	0	0	0
1	0	0	0
1	0	0	0
1	0	0	0
1	0	0	0
1	1	0	0

- Mis-classification
- Multiple Classification

Threshold-Based Algorithm

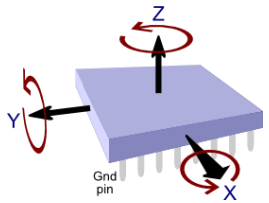
Index	BF	FF	LF	SI	Av
Sensitivity	50,02	96,66	91,60	100	84,57
Specificity	99,76	96,76	100	75,77	93,07

Advanced Threshold Algorithm

Index	BF	FF	LF	SI	Av
Sensitivity	87,42	94,83	100	100	95,56
Specificity	99,88	95,88	99,26	99,30	98,58

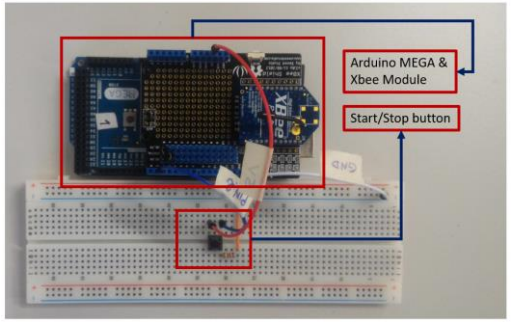
Solution:

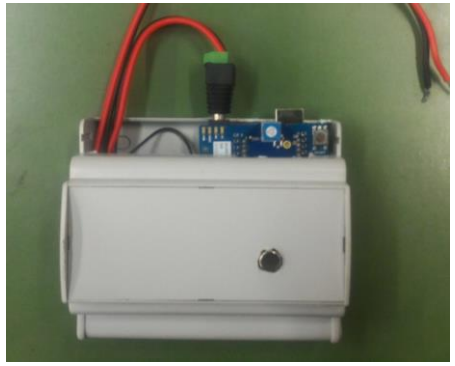
Data fusion Analysis on user position after fall

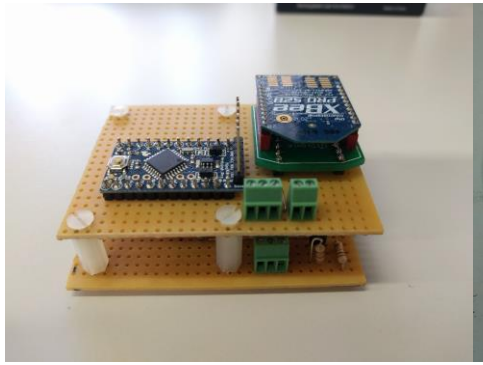


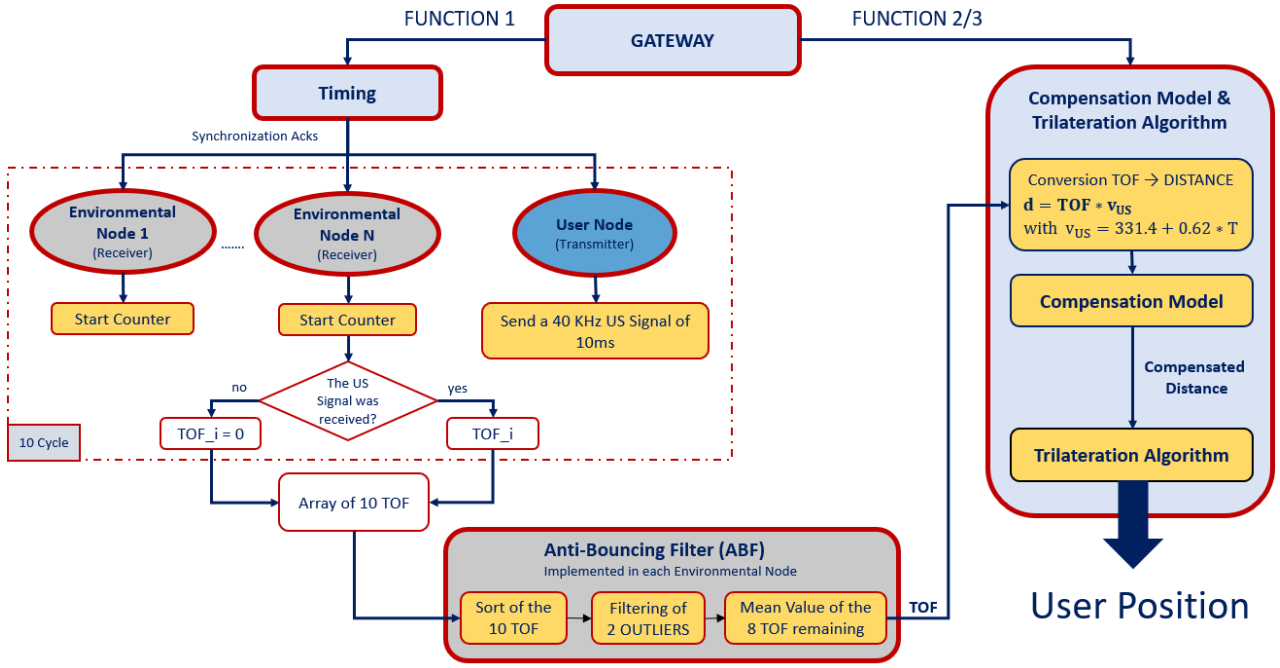
Indoor Navigation

Methodology and Devices







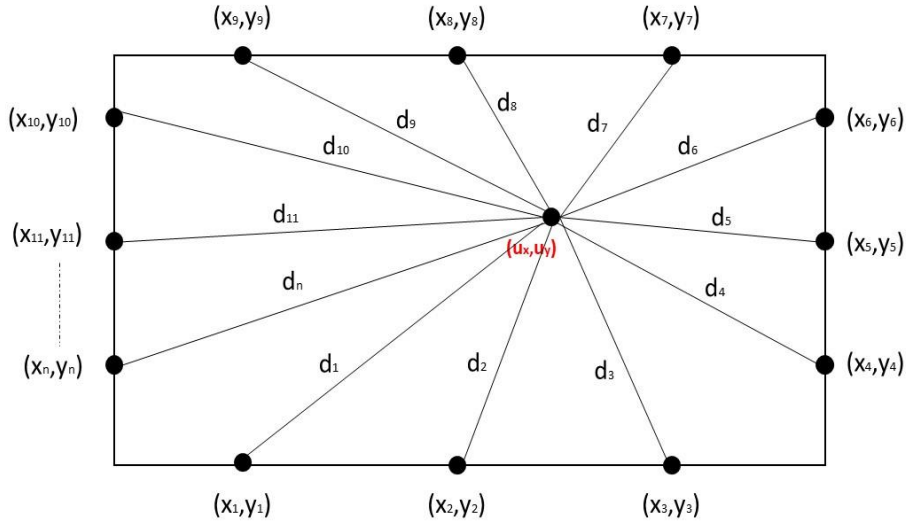


Advantages of the proposed solution:

- Continuous US distance measurement
- Autonomous Embedded Architecture
- Real-Time Localization by optimal operation Timing
- Smart Paradigms to improve the system Accuracy
- Multiple contest of applications

Indoor Navigation

Multi Trilateration

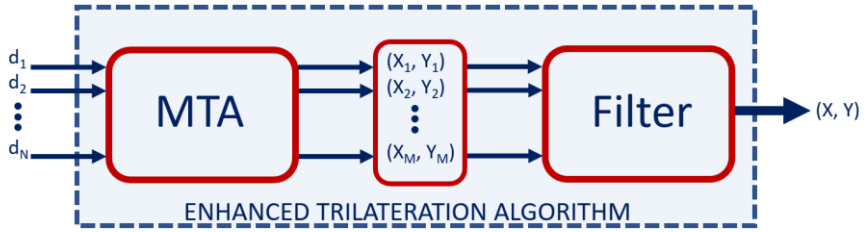


$$\underbrace{\begin{bmatrix} u_{xj} \\ u_{yj} \end{bmatrix}}_{\mathbf{u_j}} = \overbrace{\begin{bmatrix} (x_{1j} - x_{2j}) & (y_{1j} - y_{2j}) \\ (x_{1j} - x_{3j}) & (y_{1j} - y_{3j}) \end{bmatrix}}^{(\mathbf{A_j})^{-1}} \overbrace{\begin{bmatrix} (\mathbf{d_{2j}^2} - \mathbf{d_{1j}^2}) + (x_{1j}^2 - x_{2j}^2) + (y_{1j}^2 - y_{2j}^2) \\ (\mathbf{d_{3j}^2} - \mathbf{d_{1j}^2}) + (x_{1j}^2 - x_{3j}^2) + (y_{1j}^2 - y_{3j}^2) \end{bmatrix}}^{\mathbf{B_j}}$$

with $\begin{cases} j = 1,2,\dots,\mathbf{M} \text{ Number of triad} \\ (\mathbf{x_{ij}}, \mathbf{y_{ij}}) \text{ The i} - \text{th corner of the j} - \text{th triad} \\ \mathbf{d_{ij}} \text{ The user distance from the i} - \text{th corner of the j} - \text{th triad} \end{cases}$

- (x_i, y_i) Environmental Nodes Coordinates with i = 1,2,…..,N
- (u_x, u_y) User Position
- d_i Distance User / i-th Environmental Node with i = 1,2,…..,N
- Redundancy of the User Position estimates. The number of combinations is a function of N (Environmental Nodes):

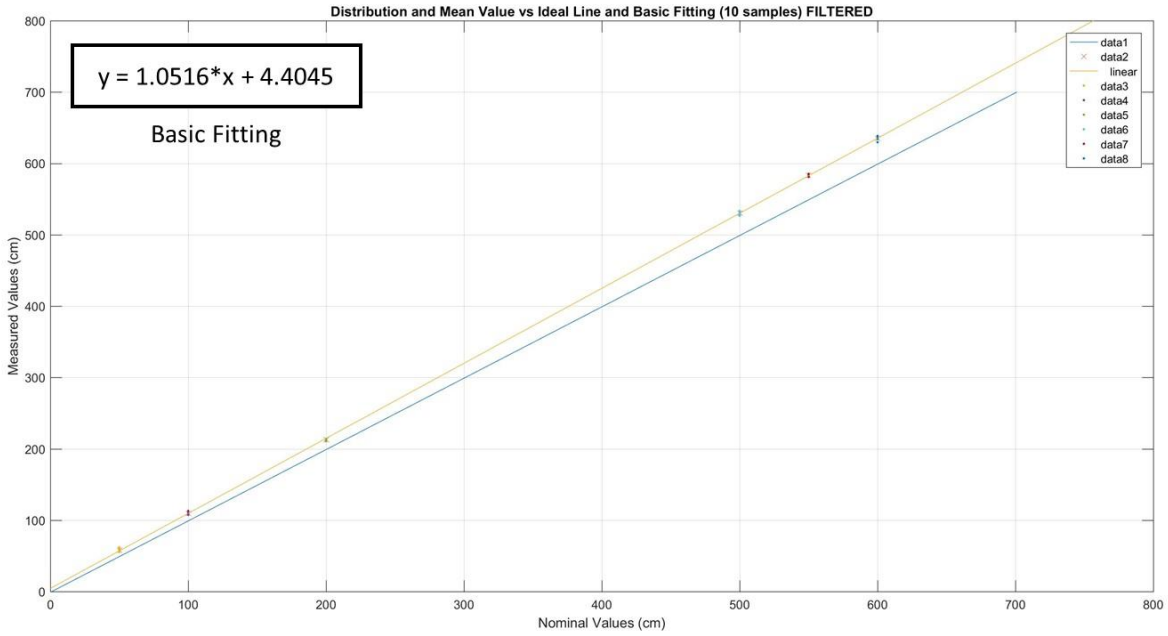
$$\mathbf{M} = \mathbf{C}(\mathbf{N}, \mathbf{3}) = \frac{\mathbf{N}!}{(\mathbf{N} - \mathbf{3})!\,\mathbf{3}!}$$



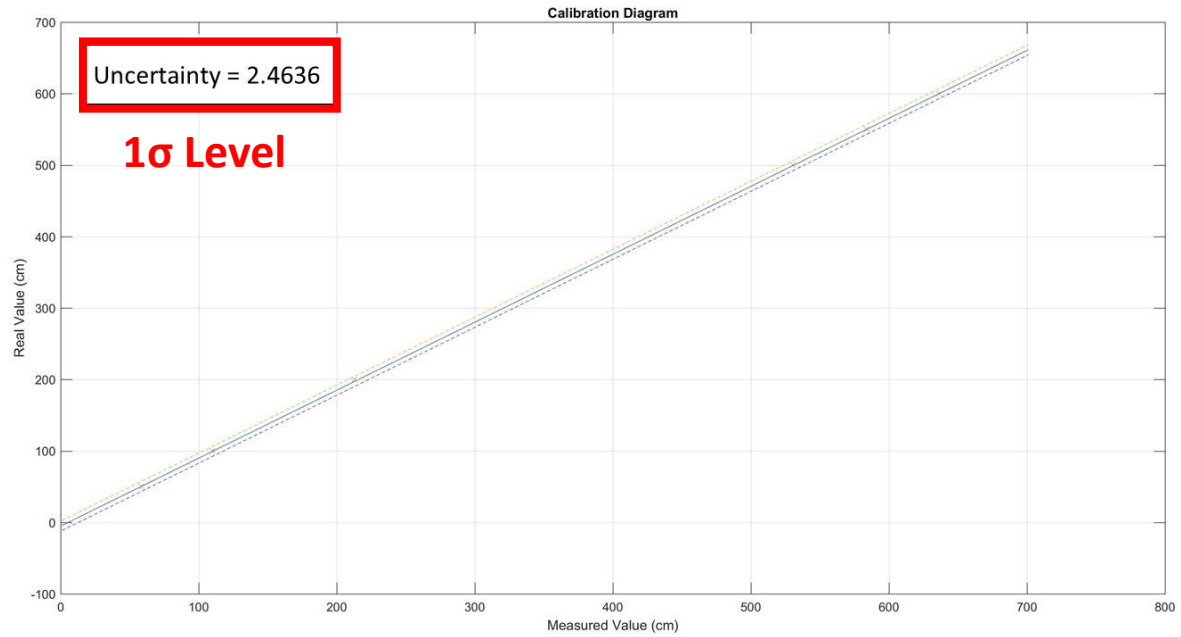
Indoor Navigation

Compensation Models

- **Trasduction Diagram (NODE A)**



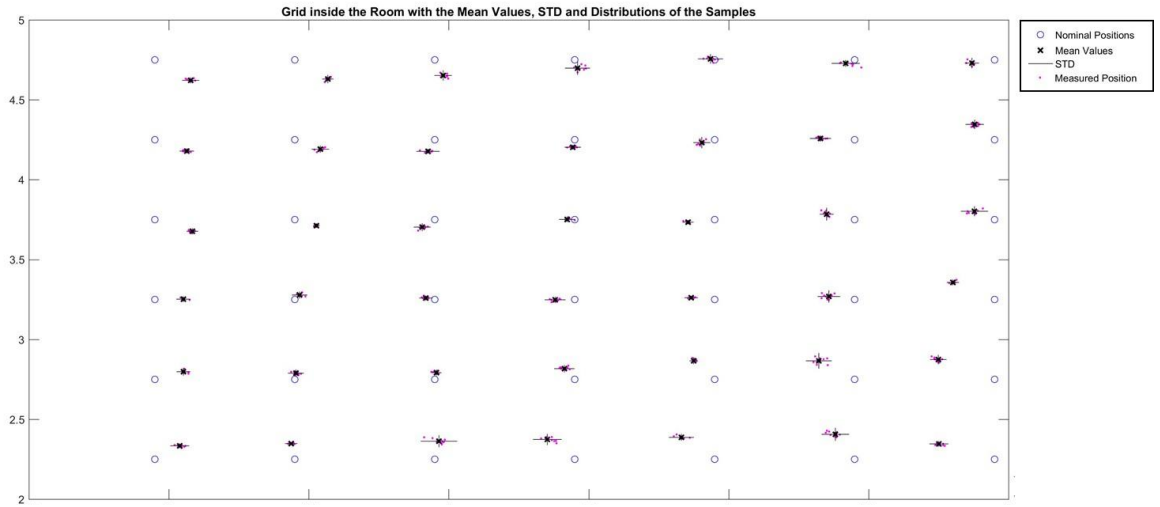
- **Calibration Diagram (NODE A)**

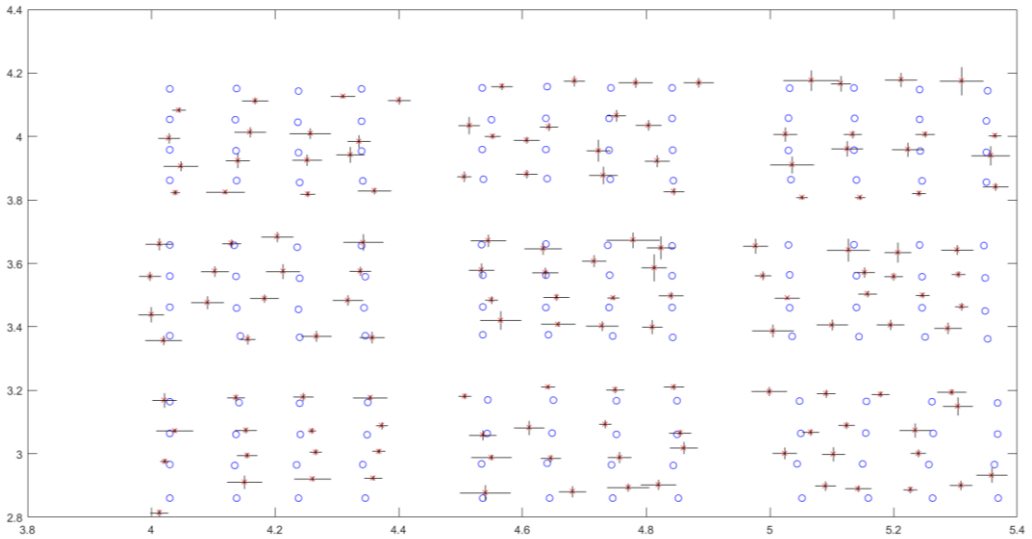


Indoor Navigation

Experimental Setup

- **Task of the Characterization:**
  - Accuracy
  - Precision
- **Nominal Positions:**
  - MEASUREMENT GRID
- **Samples collected for each Distance:**
  - Dataset of 100 samples
- **Influence parameter monitored:**
  - Temperature (°C)





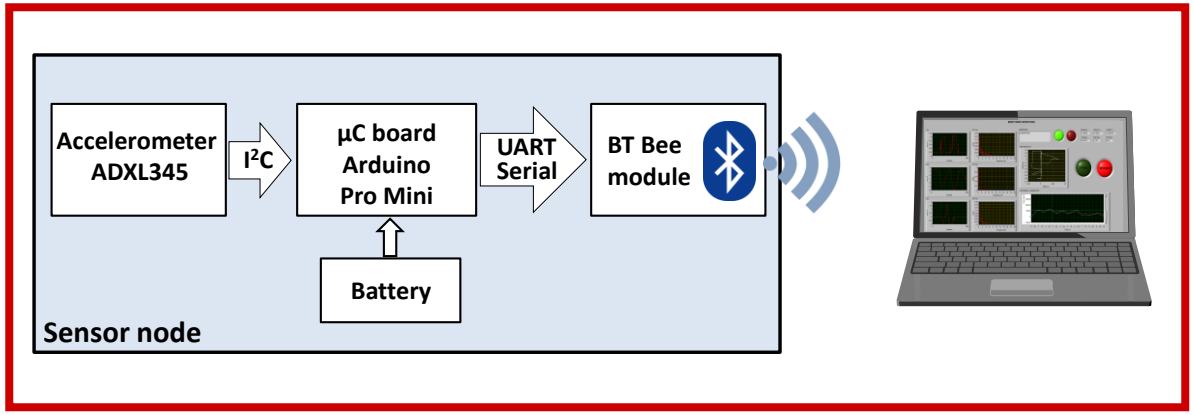
Postural instability

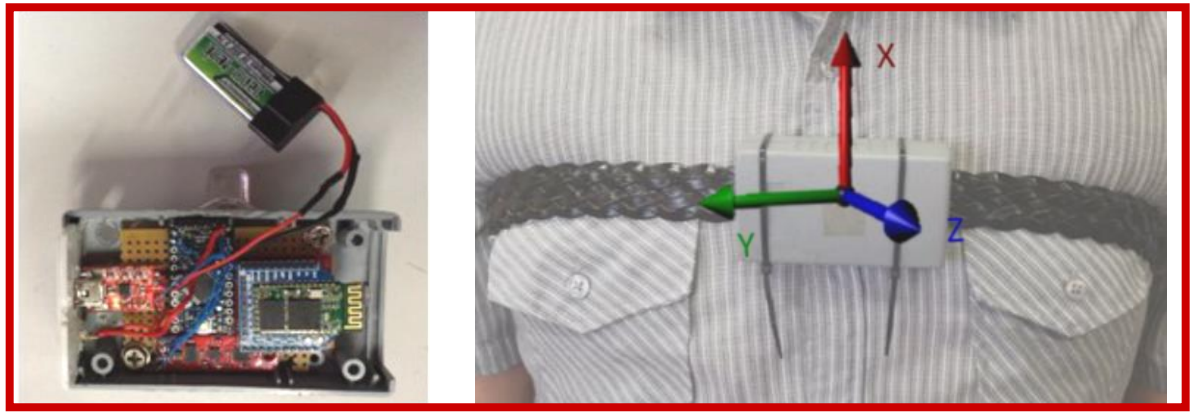
General objective:

- To have a system able to:
  - Monitor the user pathology evolution (postural instability is an early symptom of the Parkinson)
  - Validate the pharmacological therapies and rehabilitation strategy.

Implementation:

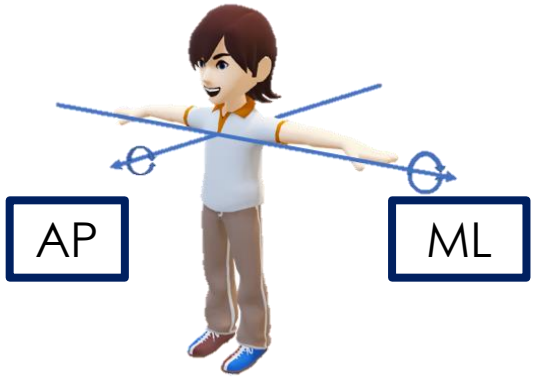
- A low-cost wearable device and advanced signal processing aimed at the continuous monitoring of the user's postural sway.

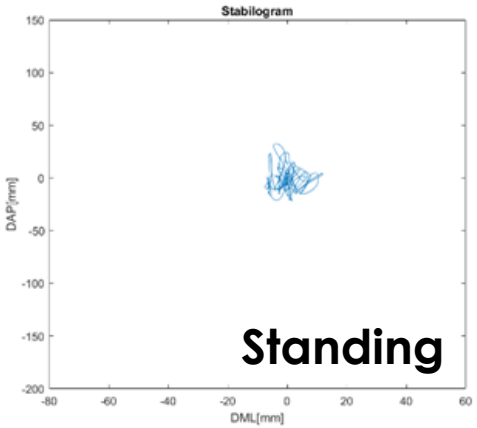


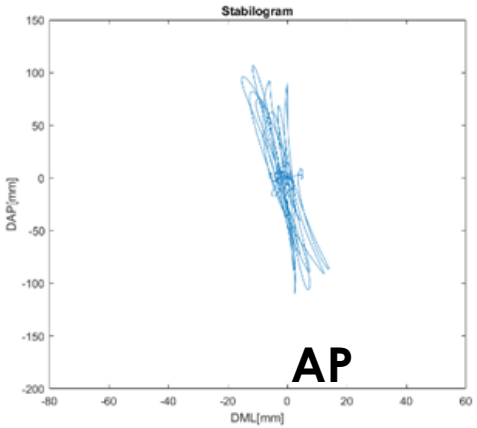


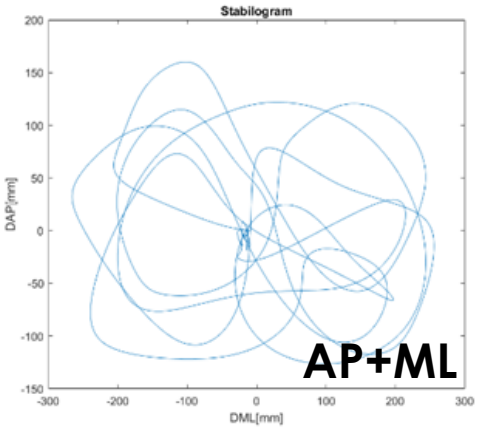
Postural instability

Stabilogram



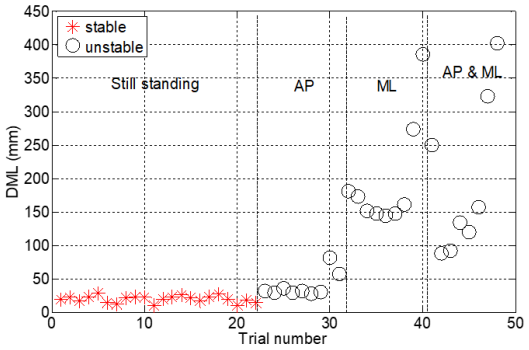


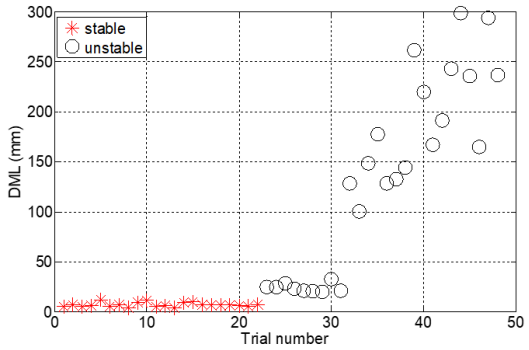


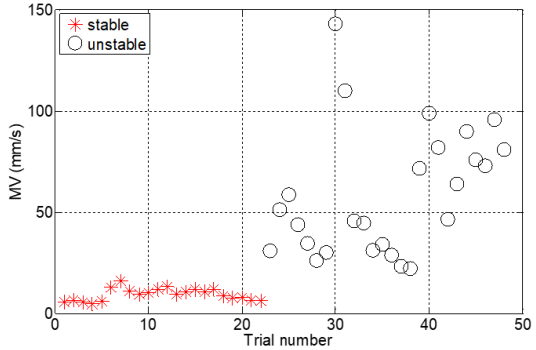


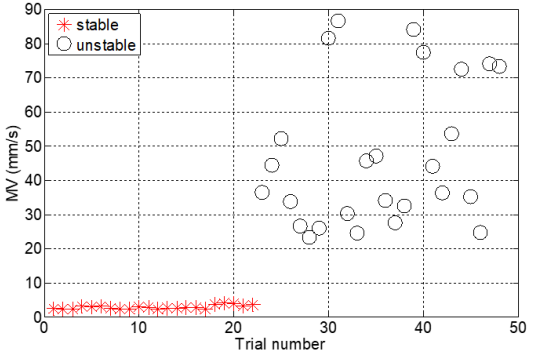
Postural instability

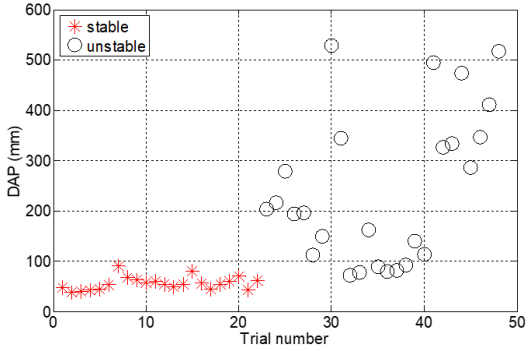
Features

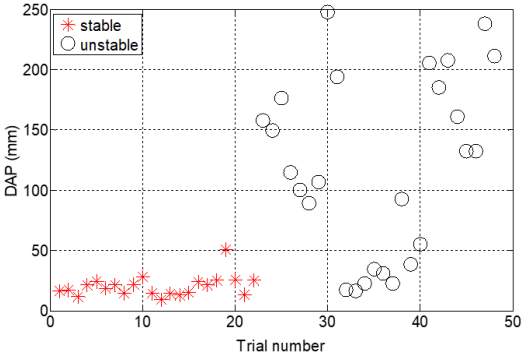


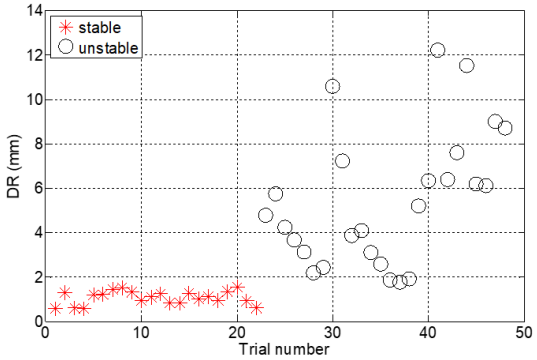


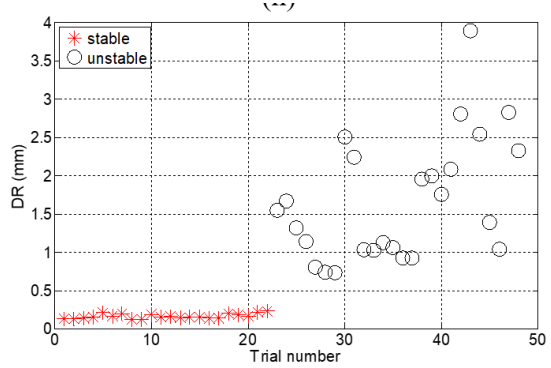






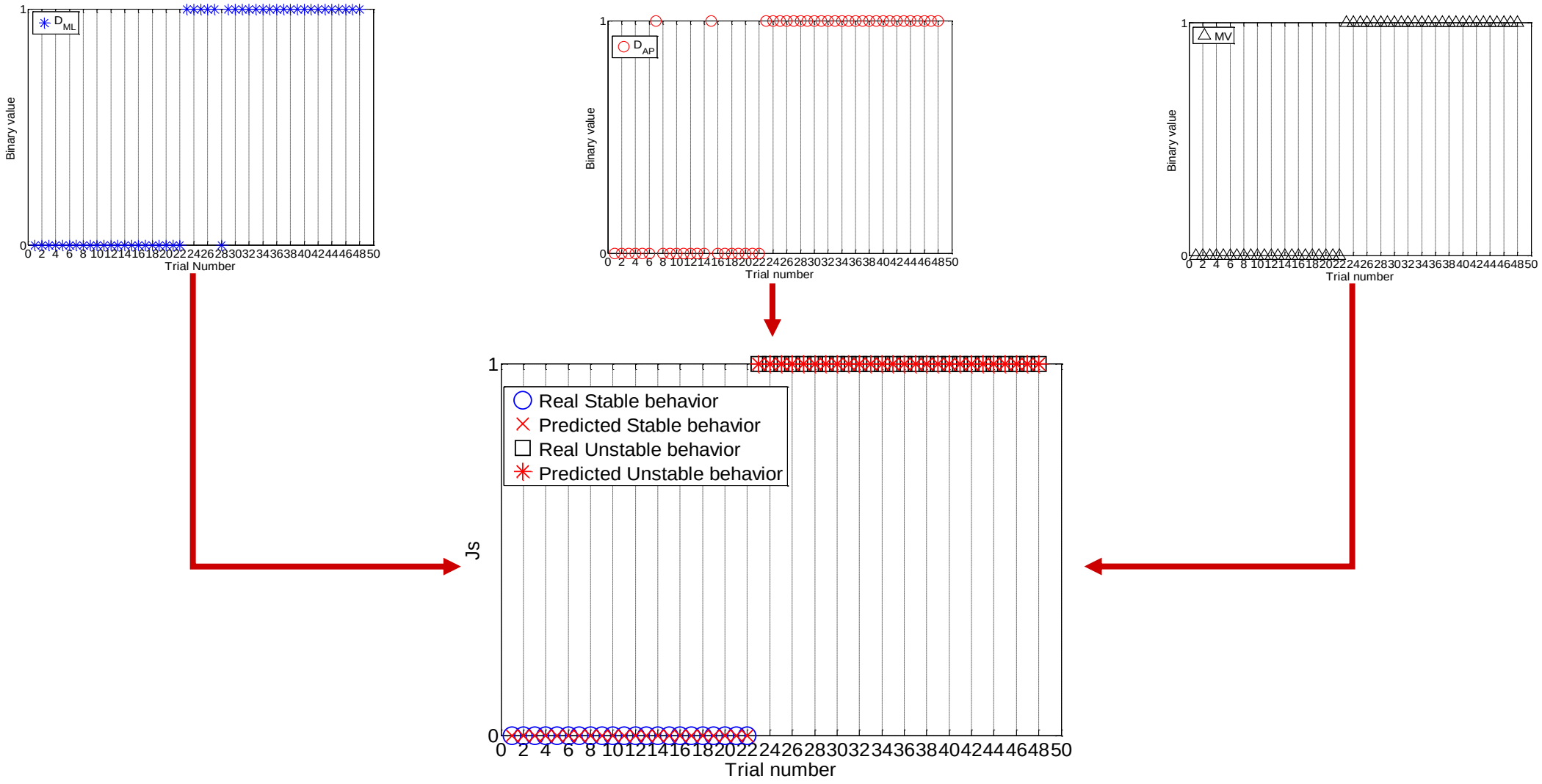






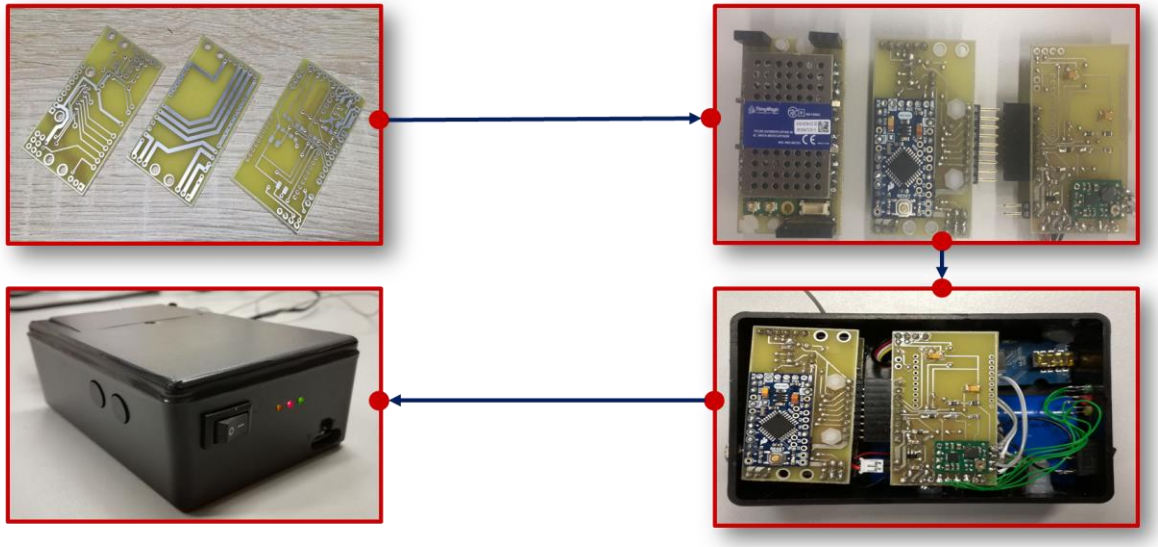
Postural instability

Features Fusion

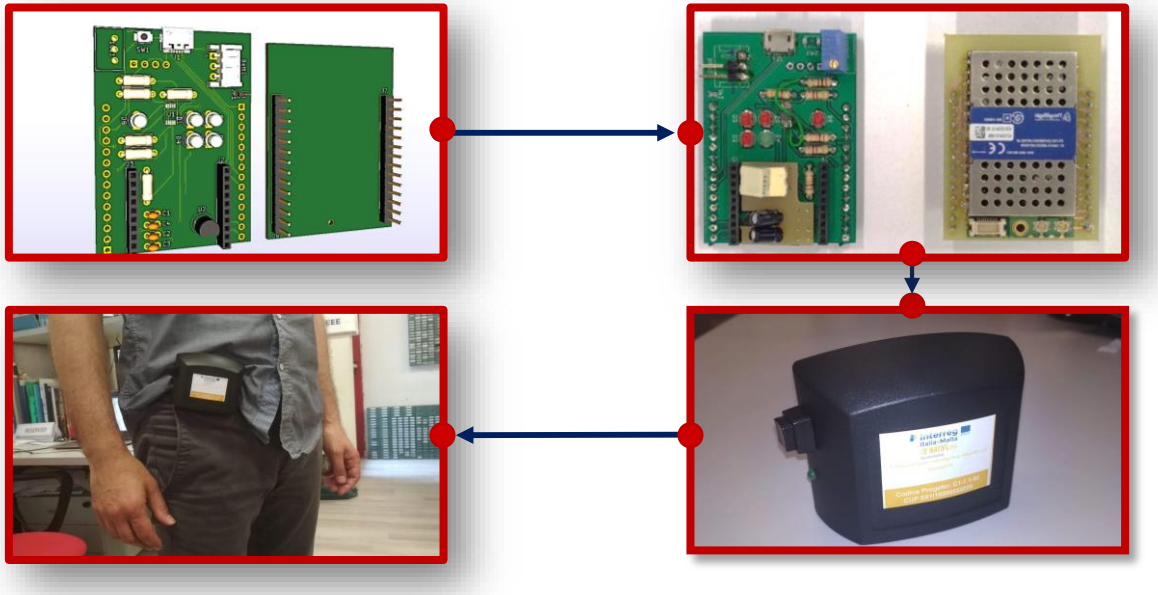


RFID-based systems

Realized Devices



Orientation system for the visually impaired



User habits monitoring

RFID-based systems

Orientation system: results

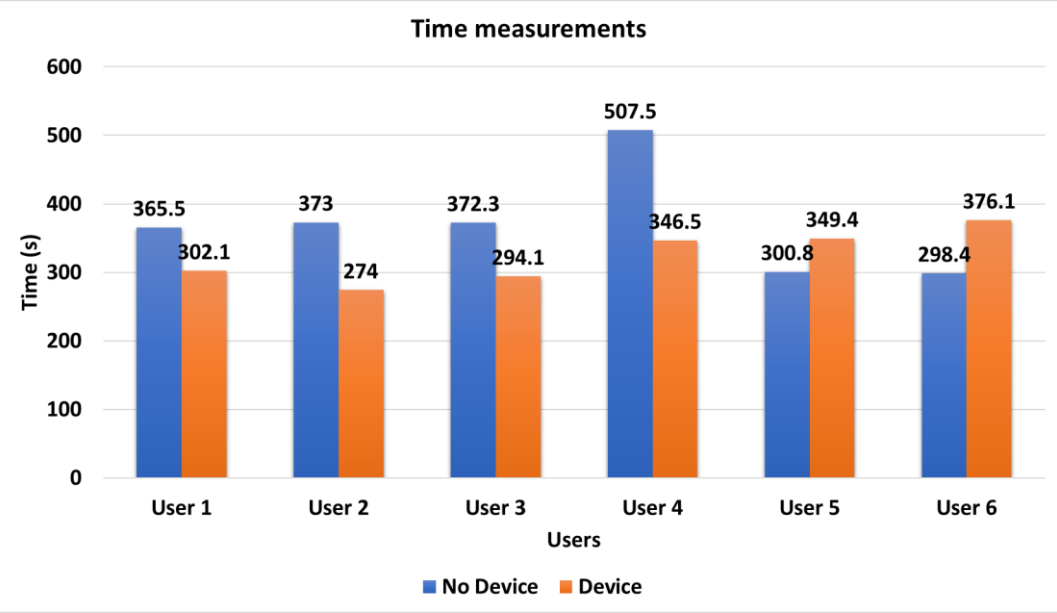
Aim:

To validate the assessment results and to quantify the effective utility of the device when used by real users.

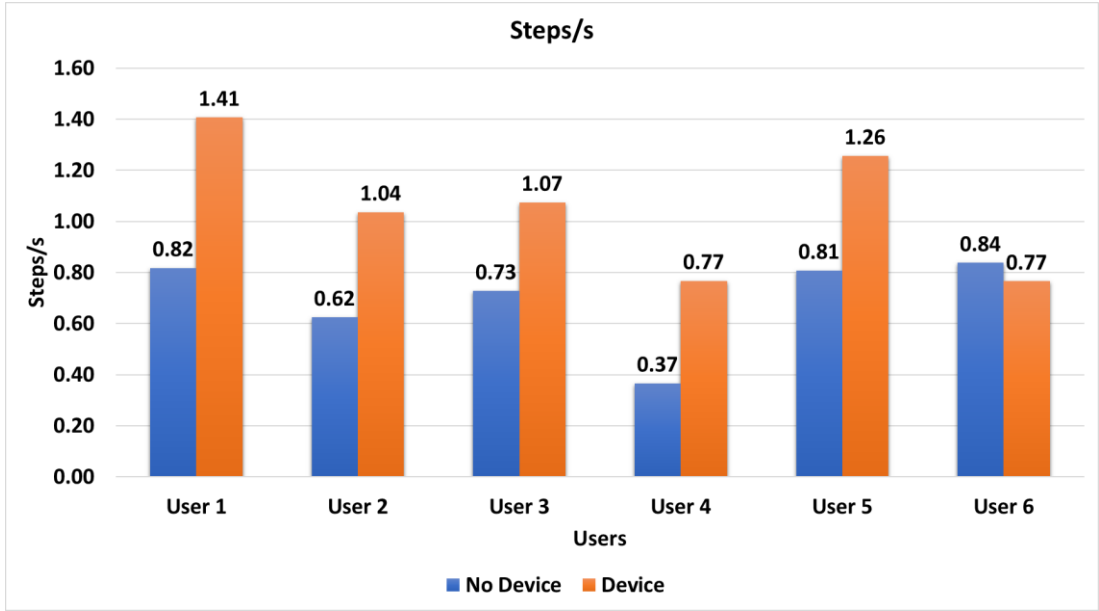
Users:

- 6 user in normal physical condition (10 trials/user) **(no end-users)**

With and without the use of the assistive system.



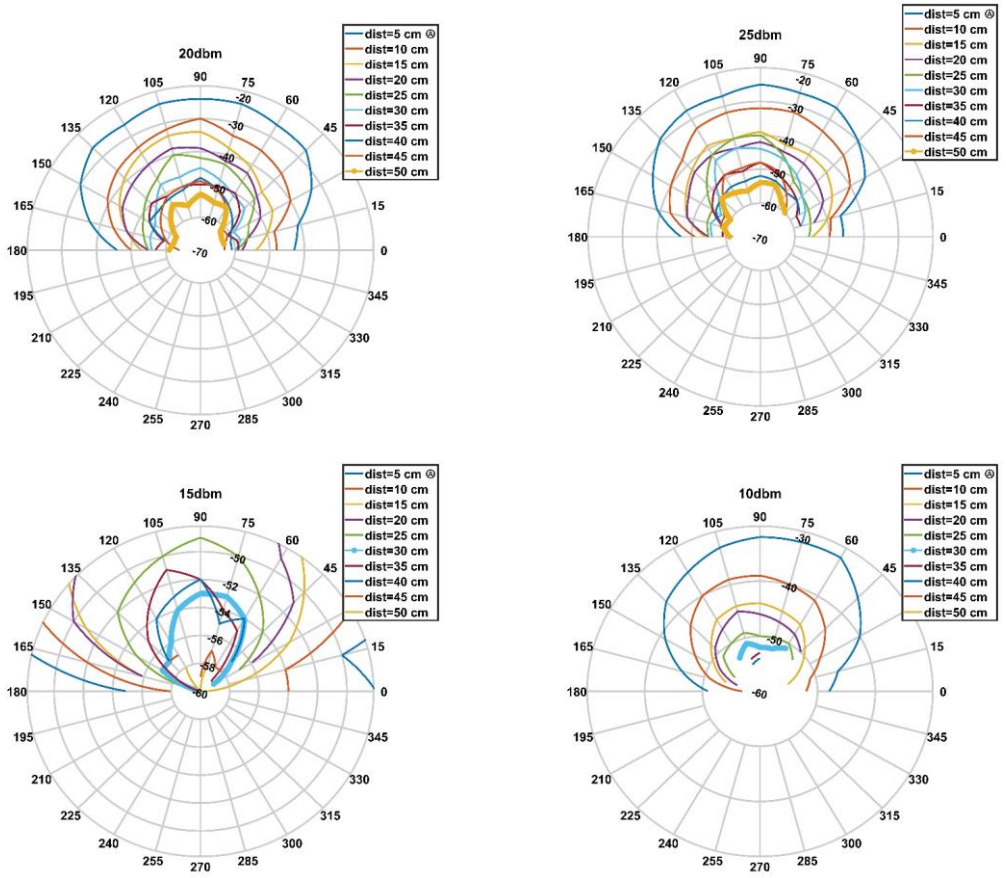
Each value is the sum of 10 trials



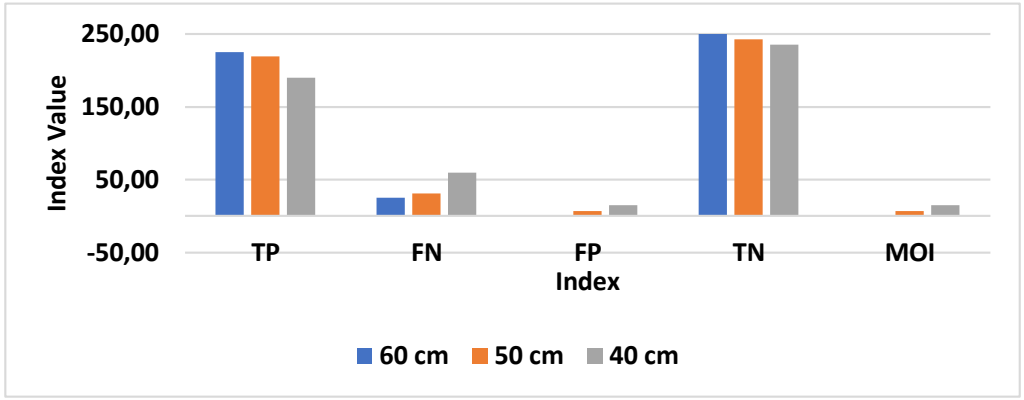
Steps/s for 10 trials

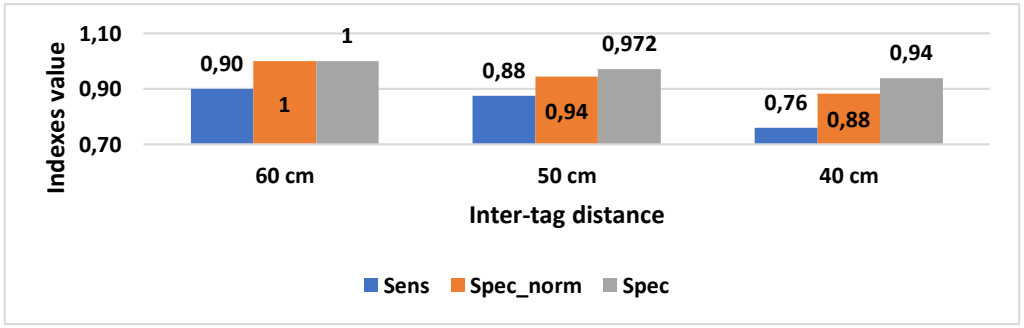
RFID-based systems

User habits monitoring system: results



To evaluate the best power to reading range ratio for the addressed application





Assessment of the device behaviour during real use

Projects & Schools & Conferences

SUMMIT

Interreg Italia-Malta NATIFLife

INAP Centro per l'Integrazione Attiva e Partecipata
Servizi per le disabilità e i DSA
Università degli Studi di Catania

AVIOT

PH.D. SCHOOL "ITALO GORINI" 2018
GENEVA, SWITZERLAND, SEPTEMBER 10 - 14, 2018

Ph.D. School ITALO GORINI
NAPLES, ITALY
SEPTEMBER 2-6, 2019

foritaal
Ambient Assisted Living
9° Forum Italiano – 2-4 Luglio 2018, Lecce

FORUM NAZIONALE DELLE MISURE | PERUGIA 2019

foritaal
Ambient Assisted Living
10° Forum Ancona 2019

MISURE 2018

2019 IEEE SENSORS APPLICATIONS SYMPOSIUM
MARCH 11-13, 2019 | SOPHIA ANTIPOLIS, FRANCE

Publication

Journal

- Advanced Solutions Aimed at the Monitoring of Falls and Human Activities for the Elderly Population

B. Andò, S. Baglio, S. Castorina, R. Crispino, V. Marletta, MDPI-Technologies, vol. 7, no. 3, pp. 59

- A smart inertial system for fall detection (Accepted with minor revision)

B. Andò, S. Baglio, S. Castorina, R. Crispino, V. Marletta, JAIHC (Journal of Ambient Intelligence and Humanized Computing)

- A Fluxgate-Based Approach for Ion Beam Current Measurement in ECRIS Beamline: Design and Preliminary Investigations

B. Andò, S. Baglio, R. Crispino, S. Graziani, V. Marletta, A. Mazzaglia, V. Sinatra, D. Mascali, G. Torrisi, IEEE Transactions on Instrumentation and Measurement, vol. 68, no. 5, pp. 14771484

- A measurement strategy to assess the optimal design of an RFID-based navigation aid

B. Andò, S. Baglio, V. Marletta, R. Crispino, A. Pistorio, IEEE Transactions on Instrumentation and Measurement, vol. 68, no. 7, pp. 23562362

Two more under review: MDPI-Sensors, IEEE Transactions on Instrumentation and Measurement

Publication

Proceedings

- NATIFLife-A Smart Sensor Network for Assistive Domotics

B. Andò, S. Baglio, S. Castorina , R. Crispino, S. Graziani, V. Marletta, L. Porcaro, S. Salupo, 2019 IEEE International Symposium on Measurements & Networking (M&N)

- A measurement procedure for the optimization of a distributed indoor localization system

B. Andò, S. Baglio, S. Castorina, R. Crispino, V. Marletta, 2019 IEEE International Symposium on Measurements & Networking (M&N)

- A sensing platform for postural behavior assessment

B. Andò, S. Baglio, R. Crispino, V. Marletta, V. Dibilio, G. Mostile, A. Nicoletti, M. Zappia, 2019 IEEE International Symposium on Measurements & Networking (M&N)

- A measurement strategy to assess performances of Fall Detector paradigms

B. Andò, S. Baglio, R. Crispino, V. Marletta, 2019 IEEE International Instrumentation and Measurement Technology Conference (I2MTC)

- An RF-ID based solution of Assistive Technology for User Activity Monitoring

B. Andò, S. Baglio, S. Castorina, R. Crispino, V. Marletta, 2019 IEEE Sensors Applications Symposium (SAS)

- An inkjet printed pressure sensor for applications in Active Ageing monitoring

B. Andò, S. Baglio, S. Castorina, R. Crispino, V. Marletta, 2019 IEEE Sensors Applications Symposium (SAS)

- A Smart Inertial Pattern for the SUMMIT IoT Multi-platform

B. Andò, S. Baglio, R. Crispino, L. L'Episcopo, V. Marletta, M. Branciforte, M. C. Virzì, Italian Forum of Ambient Assisted Living, pp. 311-319

Publication

- An Embedded Localization System for the SUMMIT IoT Multi-platform

R. Crispino, B. Andò, S. Baglio, V. Marletta, Italian Forum of Ambient Assisted Living, pp. 377-384

- A fluxgate based approach for ion beam current measurement in electron cyclotron resonance ion sources beamline

B. Andò, S. Baglio, R. Crispino, S. Graziani, V. Marletta, A. Mazzaglia, V. Sinatra, D. Mascali, G. Torrisi, IEEE International Instrumentation and Measurement Technology Conference (I2MTC)

- A pressure measurement for pull test validation in postural instability assessment

B. Andò, S. Baglio, R. Crispino, V. Marletta, V. Dibilio, G. Mostile, A. Nicoletti, M. Zappia, 2018 IEEE Sensors Applications Symposium (SAS)

- Low Cost Inkjet Printed Sensors: From Physical to Chemical Sensors

B. Andò, S.e Baglio, V. Marletta, R. Crispino, S. Castorina, A. Pistorio, G. Di Pasquale, A. Pollicino, Convegno Nazionale Sensori, pp. 297-308

- A NeuroFuzzy approach for Fall detection

B. Ando, S. Baglio, V. Marletta, R. Crispino, International Conference on Engineering Technology and Innovation (ICE/ITMC), pp. 1312-1316

- Video tutorial for the IEEE Instrumentation and Measurement Society

Ruben Crispino http://ieee-ims.org/evts/video-tutorial/strain-gauge-theory-and-application

Thanks for Listening