



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

SEHM2 yearly assessment

HW & SW sensors development for acoustic and ultrasonic SHM

Michelangelo M. Malatesta

Oct 22nd, 2019

- Hardware development
 - Energy harvesting
 - Wireless solutions for Sensor nodes
 - New Generation: Compact and modular Sensor node
- Signal processing
 - GWs localization algorithms
 - DoA estimation based on CWT
 - Localisation based on WFT
- Heterogeneous sensor network characterization
 - Concrete beam
 - Cantilever & steel beam

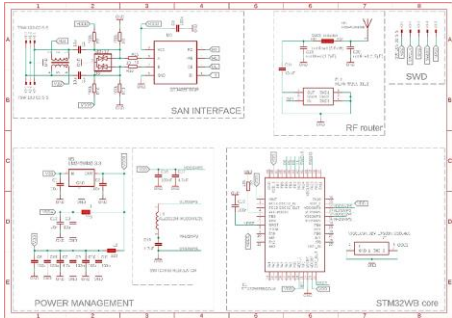
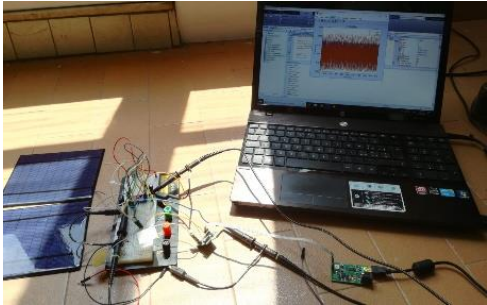
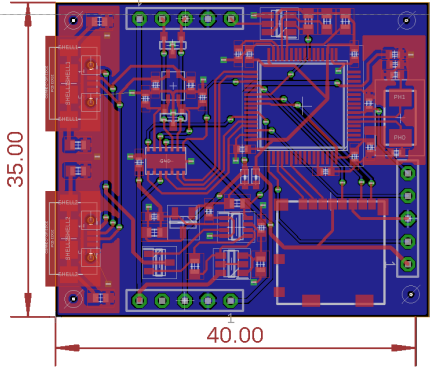
Modularity improvement

Cable reduction approach

Multi-layer approach

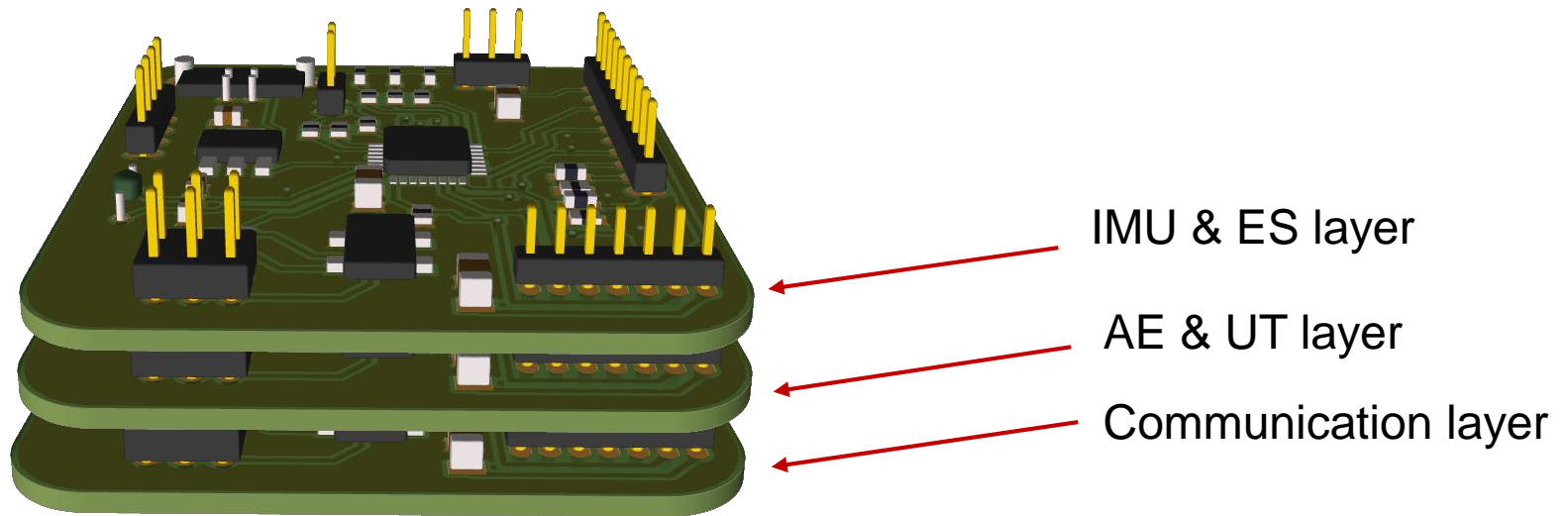
Energy harvesting (solar panels)

Wireless (BLE)



Multilayer sensor node

3

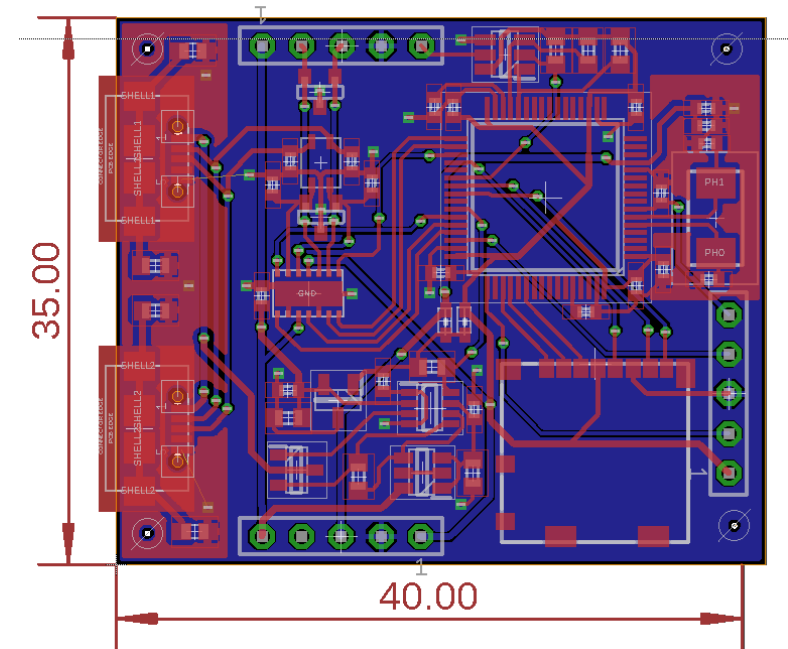


Communication layer

4

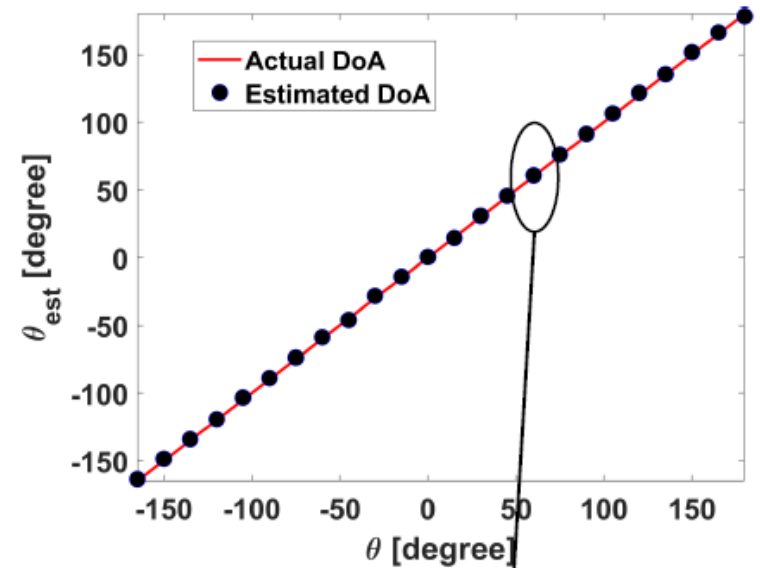
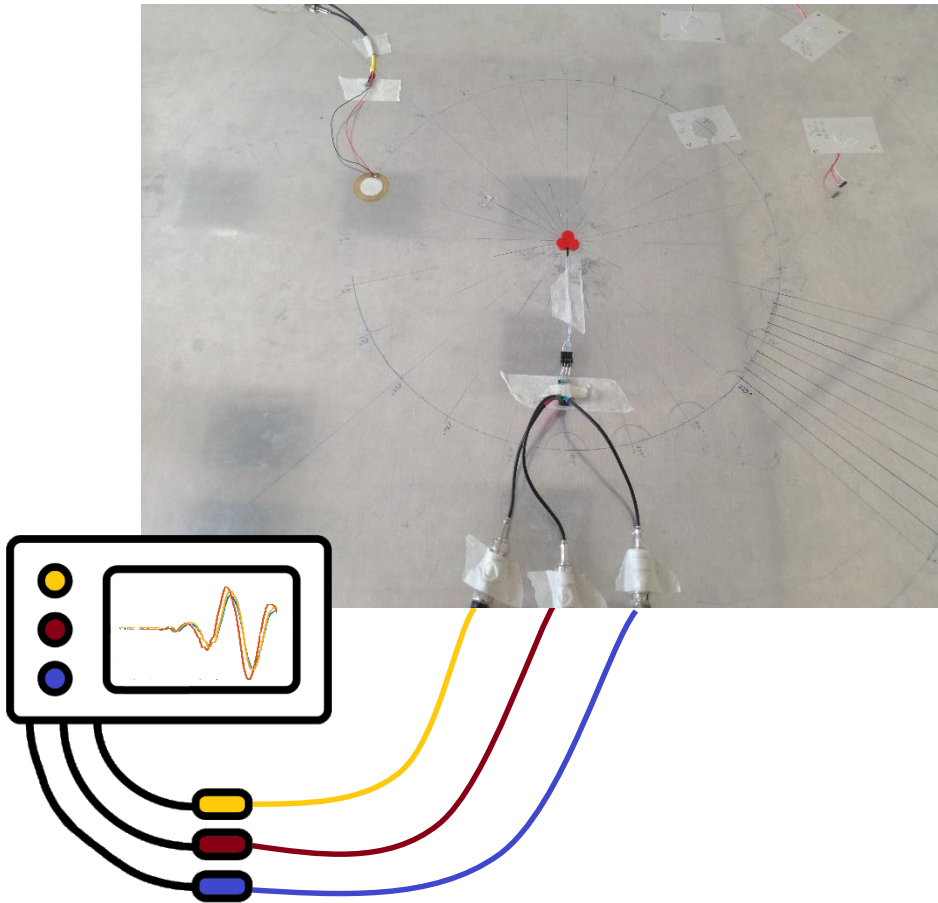
Main Features

- STM32F4 based board
- Dual CAN protocol, horizontal and vertical
- SD external memory
- USB connectors
- External 8MHz oscillator
- Advanced protection circuit
- One wire protocol for vertical WFE wake up



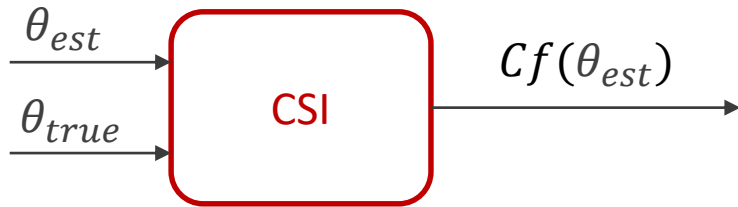
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DoA estimation by CWT decomposition ⁸

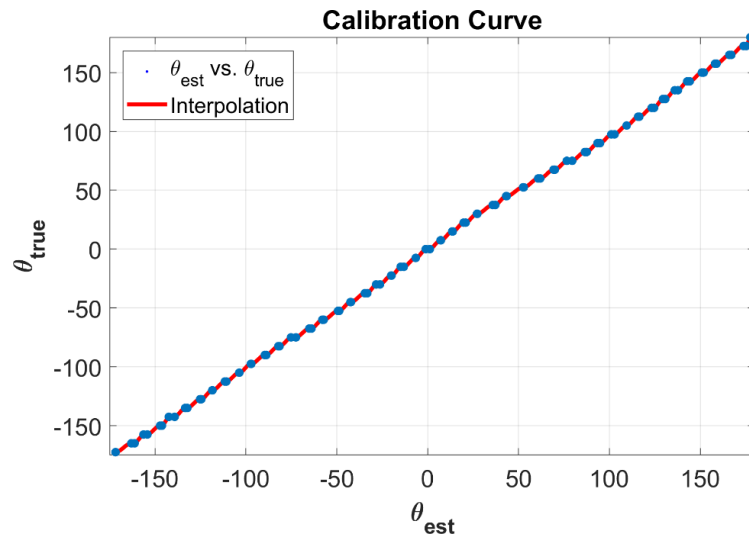
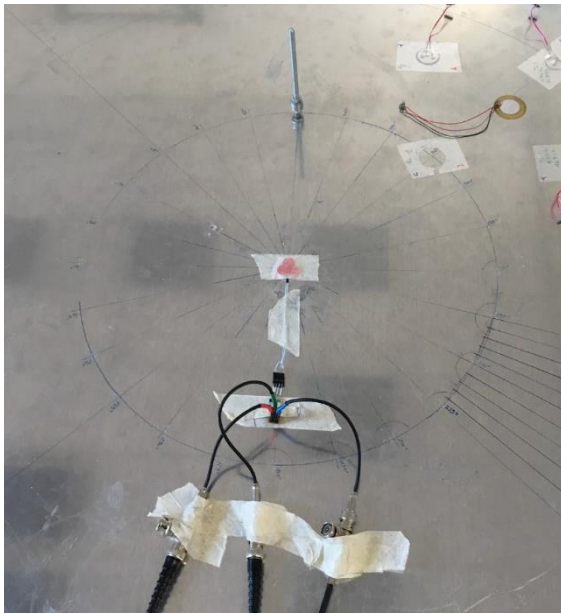


MAXIMUM ERROR: 1.74°
AVERAGE ERROR: 1.15°

DoA estimation by CWT decomposition ⁹



<u>After calibration</u>	<u>Before calibration</u>
Maximum error : 0.8°	Maximum error : 4.8°
Average error : 0.05°	Average error : 1.8°

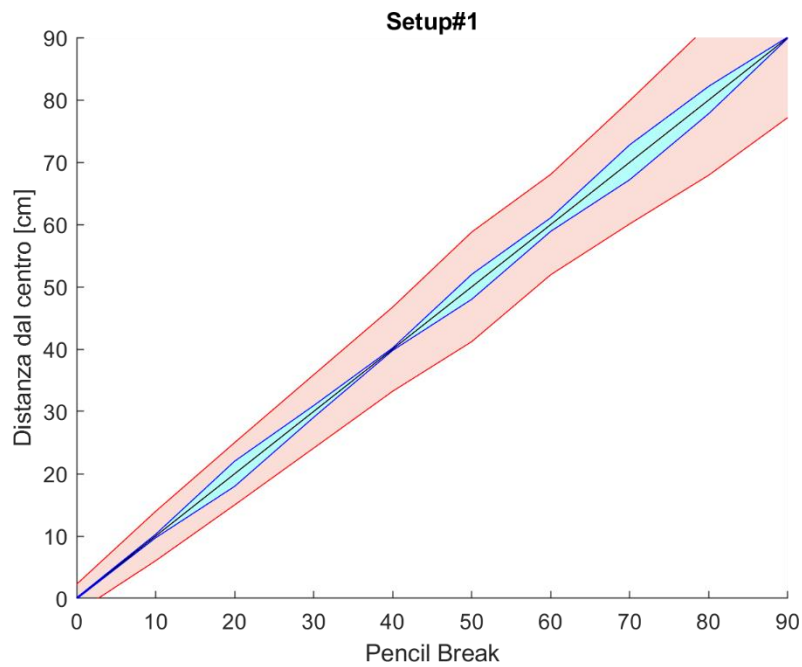


Localisazion based on WFT

#PB [actual position[cm]]	Error AMSY-5 setup#1 [cm]	Error WFT-algorithm setup#1 [cm]	Error AMSY-5 setup#2 [cm]	Error WFT-algorithm setup#2 [cm]
#1 [0]	2.26	0.11	0.43	0.23
#2 [10]	3.96	0.28	0.25	0.08
#3 [20]	5.00	2.02	1.32	0.28
#4 [30]	5.88	0.94	0.81	1.82
#5 [40]	6.75	0.20	0.14	0.78
#6 [50]	8.79	2.00	1.35	1.31
#7 [60]	8.05	1.09	1.46	1.61
#8 [70]	9.89	2.80	1.04	1.91
#9 [80]	12.07	2.19	2.00	1.30
#10 [90]	12.82	0.10	2.43	2.54

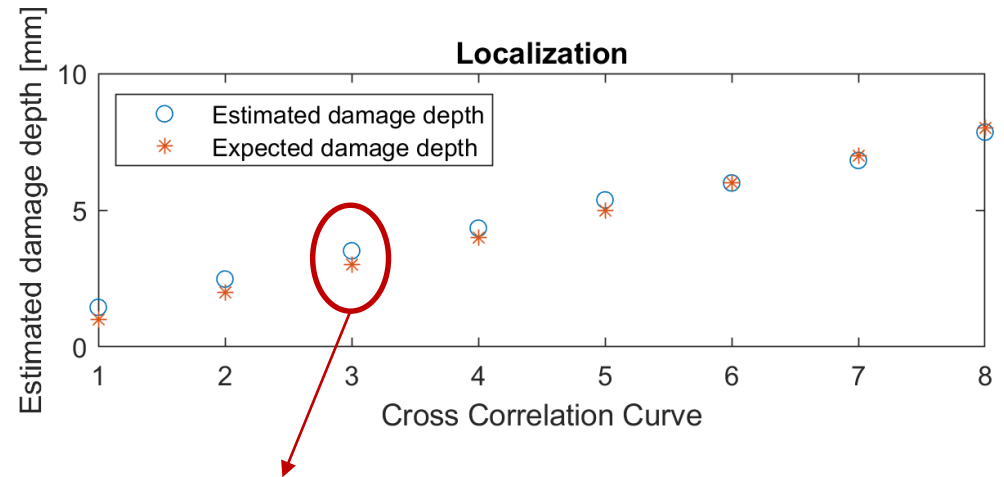
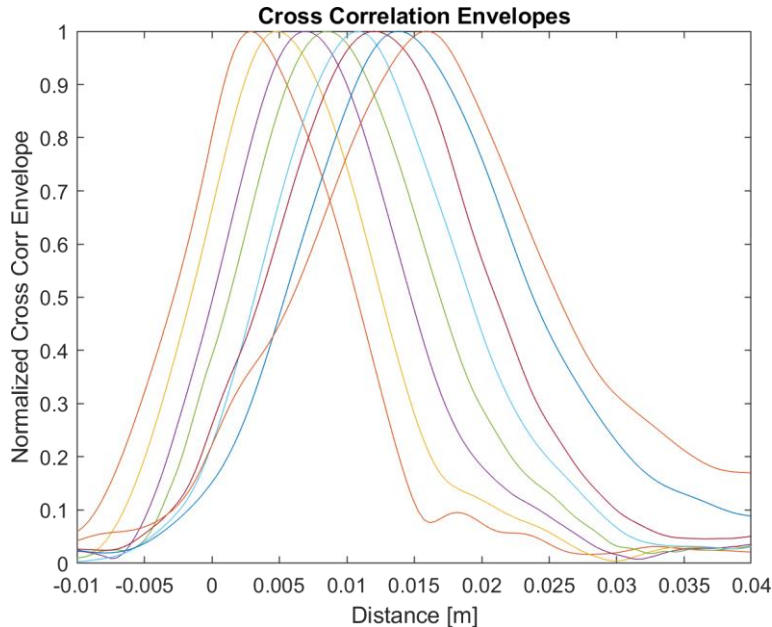


Localisazion based on WFT



Localisazion based on WFT

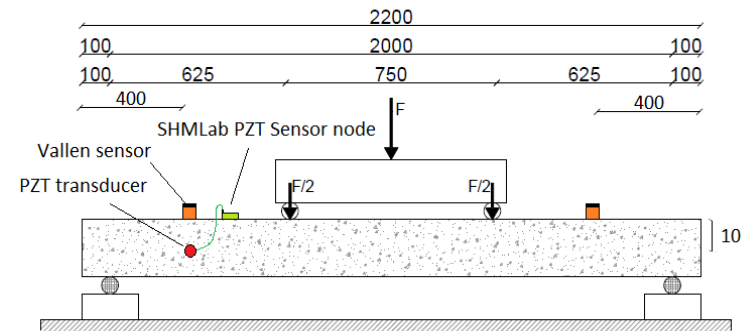
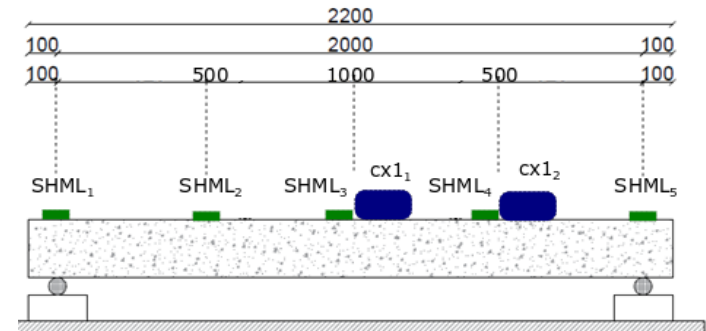
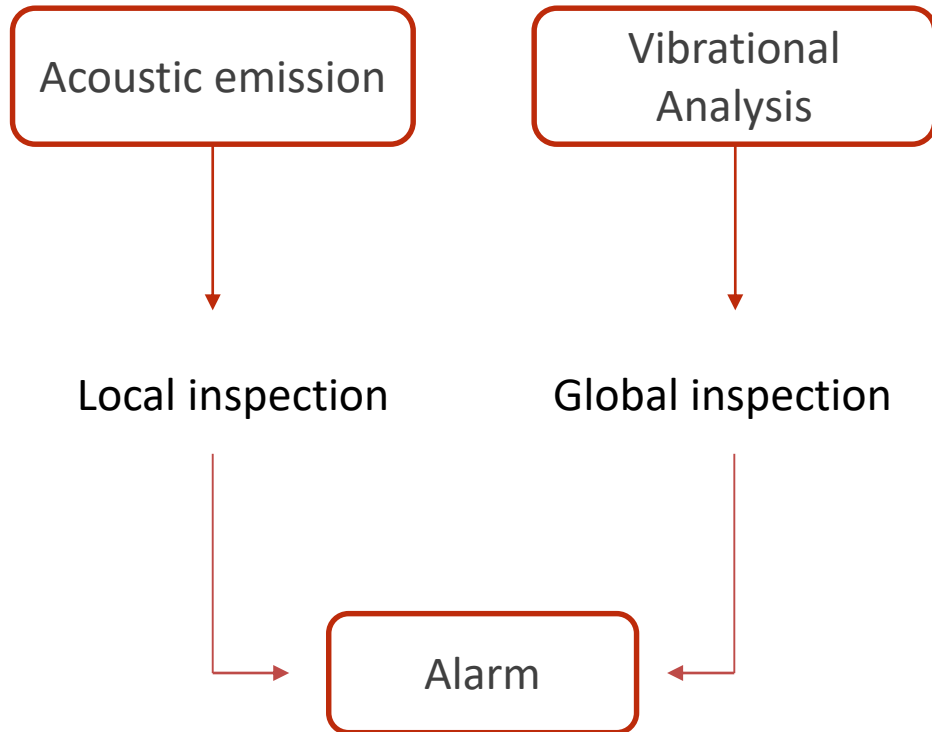
The Warping Frequency transform was also applied to the Eddy currents simulated signals referred to an Al sample containing small notches at various depths.



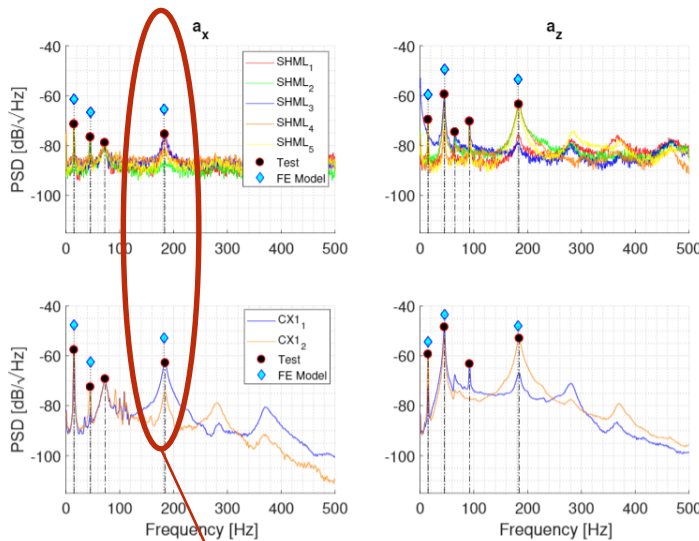
Maximum absolute localization error: 0.5mm

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Heterogeneous SN on a concrete beam



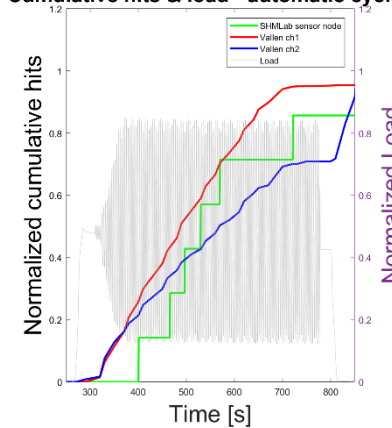
Vibrational Analysis



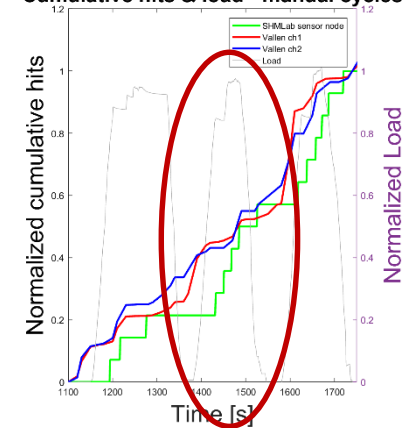
Match between SNs,
Commercial ACC and
model modes !

Acoustic emission

Cumulative hits & load - automatic cycles

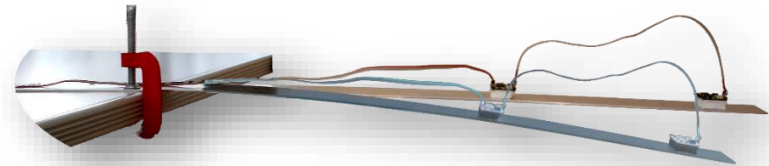
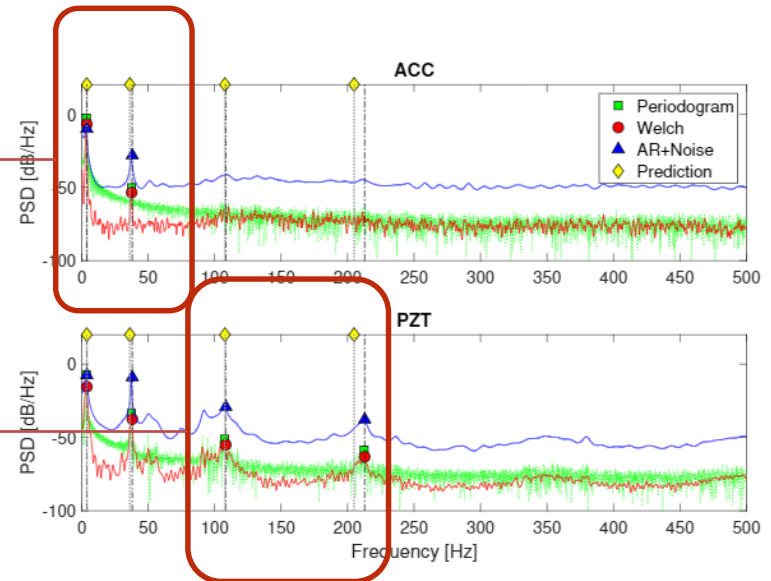
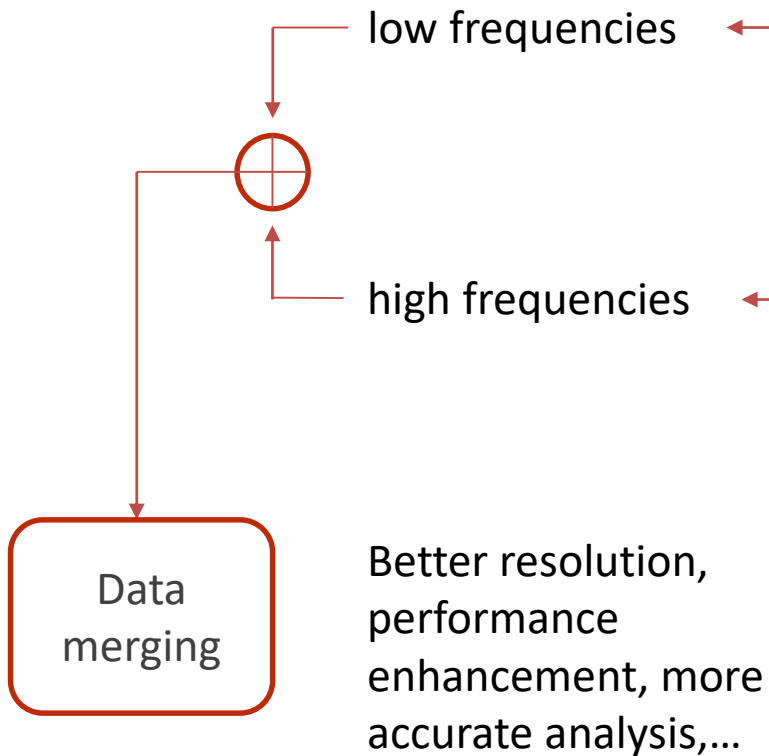


Cumulative hits & load - manual cycles



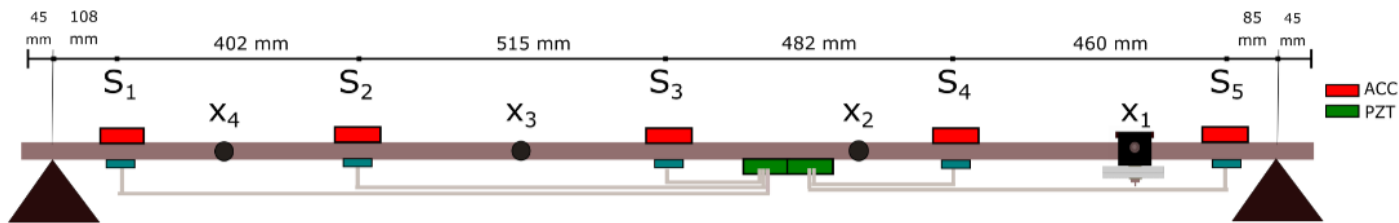
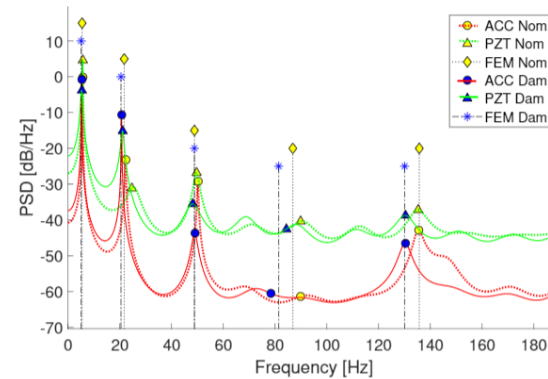
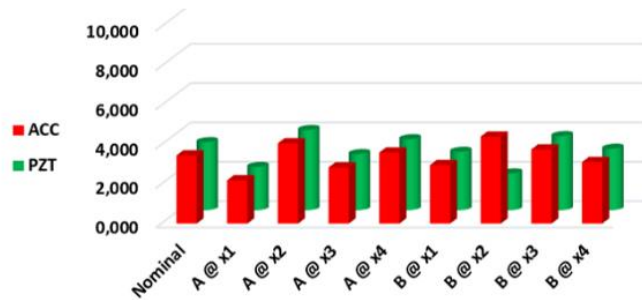
Same trends in
the AE data

Heterogeneous SN and data merging

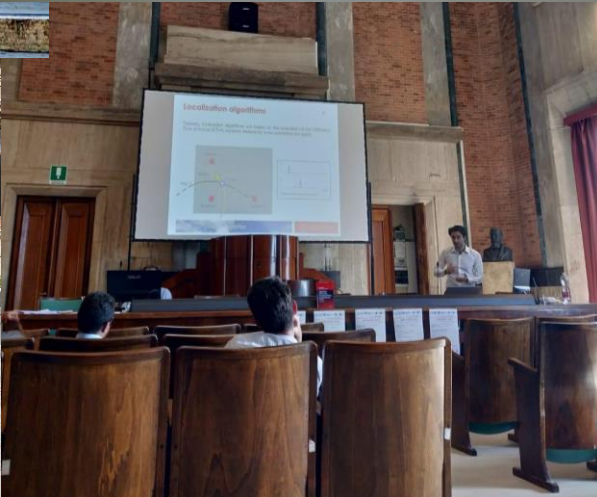
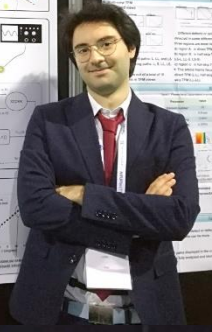
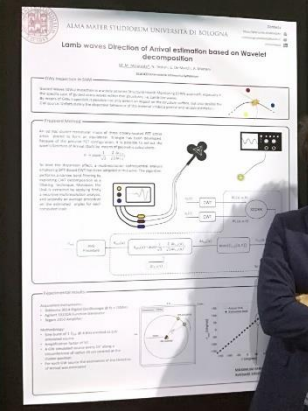
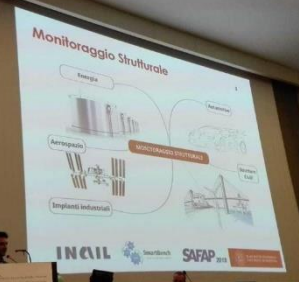


PZT network for modal analysis

The vibration harmonics have been extracted from a PZT sensor network.
The damage detection capability of the network were also investigated



- **M.M.Malatesta**, N.Testoni, A.Marzani, L.De Marchi, "Guided waves Direction of Arrival estimation based on calibrated multiresolution wavelet analysis", Proceedings ApplePies 2019, Pisa September 11-13.
- **M.M.Malatesta**, N.Testoni, , L.De Marchi, A.Marzani, "Lamb waves Direction of Arrival estimation based on Wavelet decomposition", Proceedings IEEE International Ultrasonic Symposium (IUS) 2019, Glasgow October 6 – 10.
- **M.M.Malatesta** , F.Zonzini, D.Bogomolov, Mirco Tarozzi, N.Testoni, G. Augugliaro, C. Mennuti, A.Marzani , L.De Marchi, A.Benedetti, " Monitoraggio di una trave di calcestruzzo armato con rete di sensori eterogenea miniaturizzata "Atti di convegno, AiPND, 23-25 Ottobre 2019 (Accepted)
- F.Zonzini, **M.M.Malatesta**, D.Bogomolov, N.Testoni, L.De Marchi, A.Marzani, "'Heterogeneous Sensor-Network for Vibration-based SHM'", Conference proceedings 2019 IEEE International Symposium on Measurements and Networking
- F.Zonzini, **M.M.Malatesta**, D.Bogomolov, N.Testoni, L.De Marchi, A.Marzani, "' A spectral Peak-Picking Method for On-Board Operational Modal Analysis of Multi-type Vibration-based SHM'", ANCRISST 2019 Procedia
- F.Zonzini, **M.M.Malatesta**, D.Bogomolov, N.Testoni, L.De Marchi, A.Marzani, "Vibration-based SHM with up-scalable and low-cost Sensor Networks", IEEE Transactions on Instrumentation & Measurement (submitted).
- F. Zonzini, **M.M.Malatesta**, C.Aguzzi, N.Testoni, M.Verardi and V.Scarponi, 'A Sensor network Targeted On Novel IdentifiCation of cracks', demo poster FRUCT.
- L. De Marchi, N. Testoni, **M.M. Malatesta**, G. Augugliaro, 'Processing innovativo per la localizzazione delle sorgenti di Emissioni Acustiche', Atti di Convegno SAFAP 2018, Bologna 28 e 29 Novembre, pp 411-420





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Thank you for your kind attention

