Il Ruolo delle Misure Elettriche ed Elettroniche nel PNRR

CHANGES

IEEE INSTRUMENTATION & MEASUREMENT SOCIETY® ITALY CHAPTER

75 YEARS

IEEE INSTRUMENTATION & MEASUREMENT SOCIETY®

POLITECNICO DI MILANO / 12.12.2024

CHANGES - Cultural Heritage Active Innovation for Sustainable Society

Carlo Trigona, *DIEEI Università di Catania*

PNRR - Fondazione CHANGES

CHANGES – Cultural Heritage Active Innovation for Sustainable Society - di cui Sapienza è soggetto pubblico proponente - si configura come un partnenariato costituito da 11 Università, 4 Enti di Ricerca, 3 Scuole di studi avanzati, 6 Imprese, 1 Centro di Eccellenza.

Si tratta di un Ecosistema multi-tecnologico e transdisciplinare per la formazione, la ricerca, il trasferimento tecnologico riferito alla Cultura umanistica e al Patrimonio culturale.

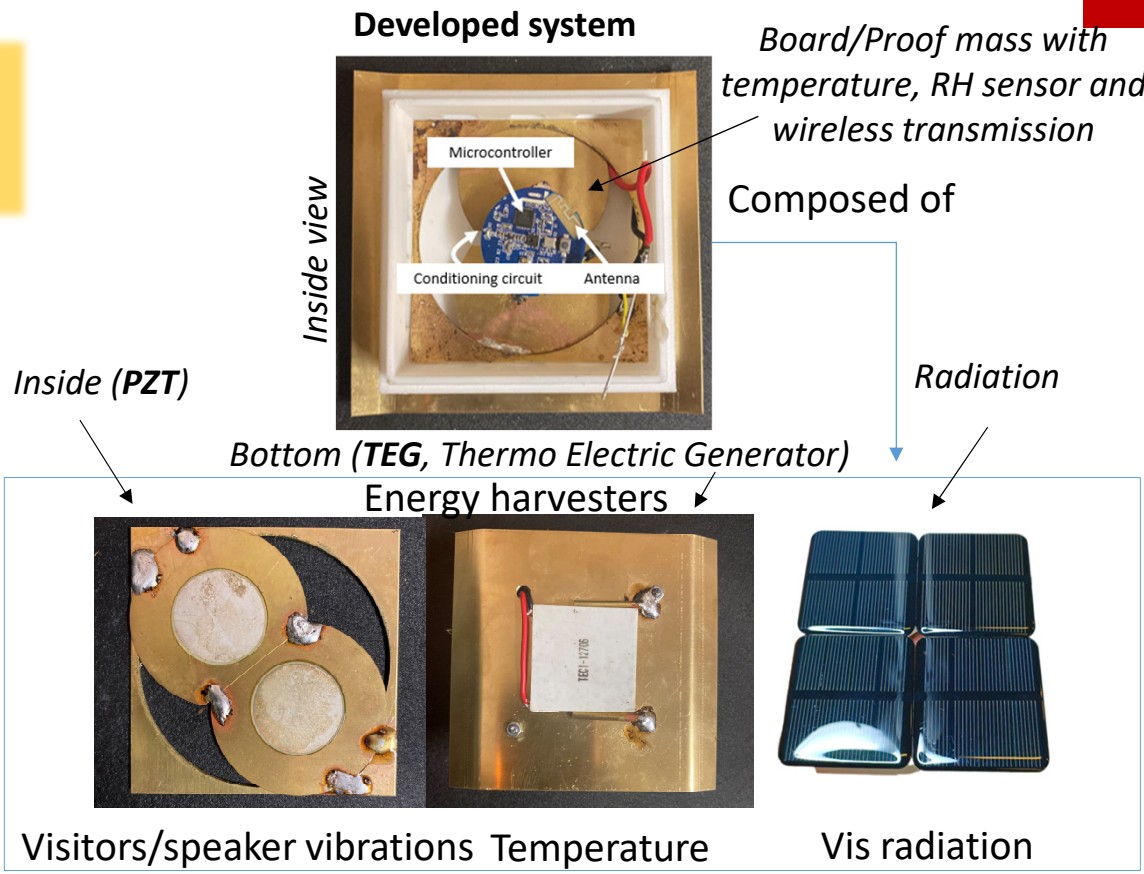
La fondazione svolge di attività strumentali e di supporto della didattica e della ricerca scientifica e tecnologica, nell'ambito del mondo dei beni culturali, della cultura e della tutela del patrimonio storico-culturale.

WP3 - Remote and close-range sensing, AI and IoT based solutions for addressing climate change threatening

Measurements through innovative IoT-based hybrid and autonomous sensors

Carlo Trigona – DIEEI UniCT

- The objective is to develop autonomous measurement systems capable of sustaining themselves from environmental energy sources such as temperature variations, radiation, and vibrations. This involves employing a hybrid solution with multiple harvesters working together.
- The conceived system is also capable of conducting microclimate measurements, including temperature and relative humidity, as well as facilitating wireless data transmission.
- The areas of application include museums, historical buildings, outdoor environments.



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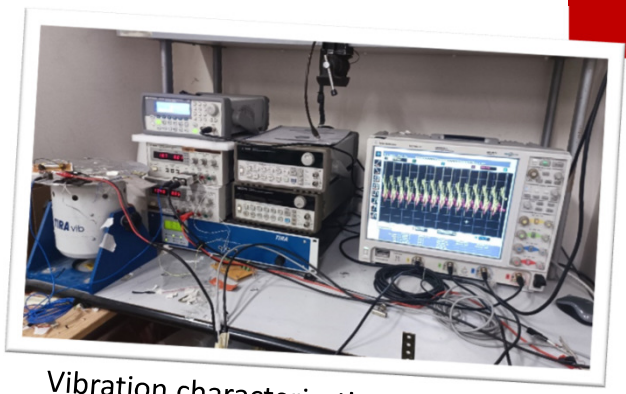
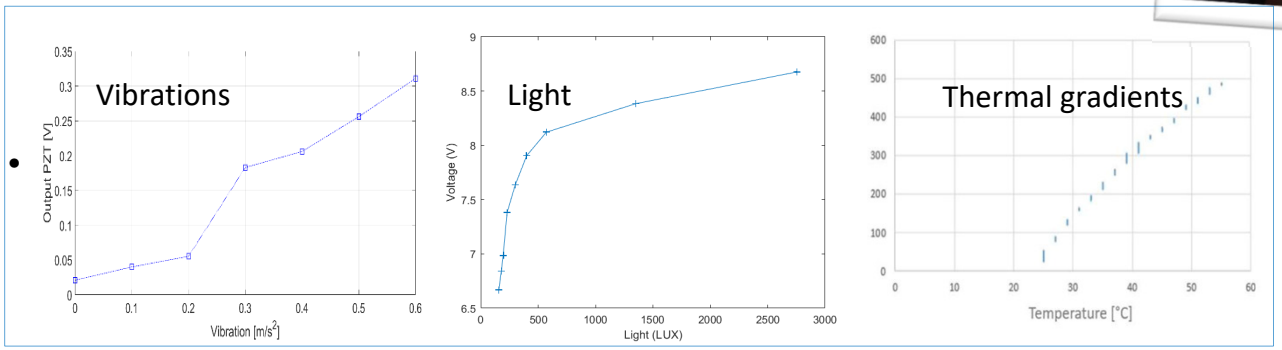
- The developed system has been characterized in the laboratory. Initially, the characterization focused on the energy harvesters. Within this framework, the measurement campaigns examined the system's performance in relation to varying levels of radiation, vibrations, and thermal gradients.

Radiation characterization

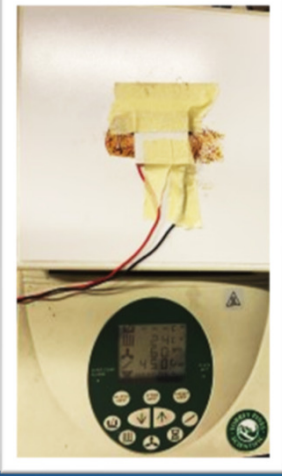


Vibration characterization



Measurements performed in laboratory.

Temperature characterization



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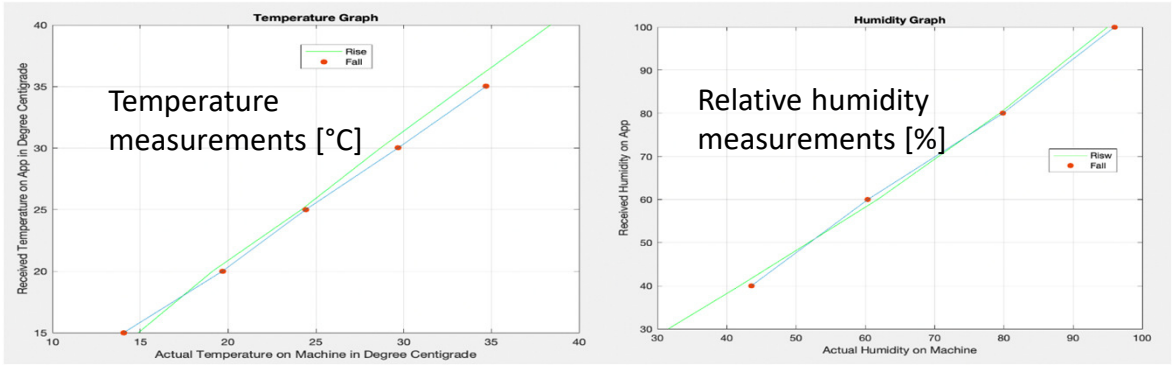
- The device has also been characterized in terms of its sensing capabilities for measuring temperature and relative humidity. Within this context, the measurement campaigns involved studying the device's performance and transmission through a controlled chamber.

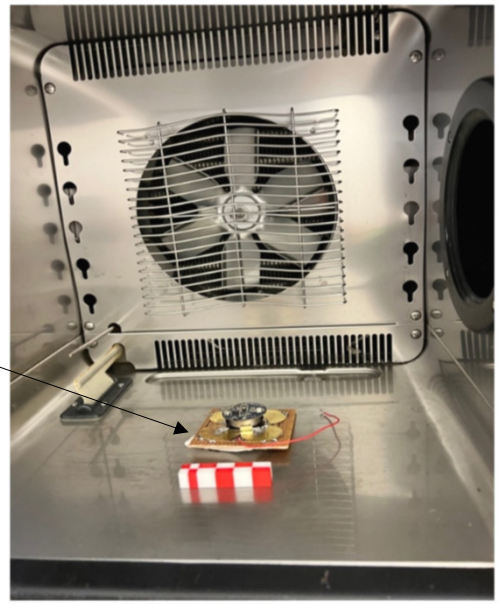


Microclimate parameters measured and successfully transmitted/received through Bluetooth and APP

Developed system

Measurements performed in laboratory

Temperature/Relative humidity controlled chamber



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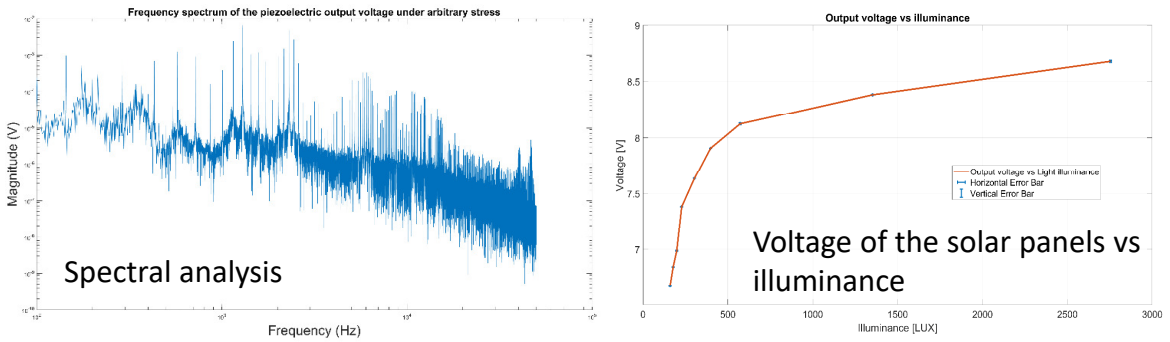
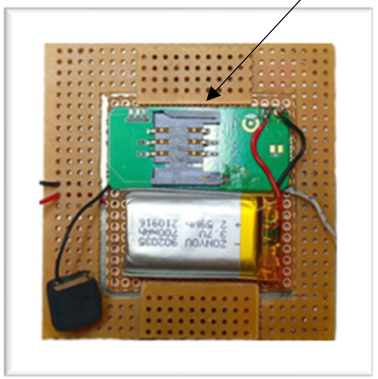
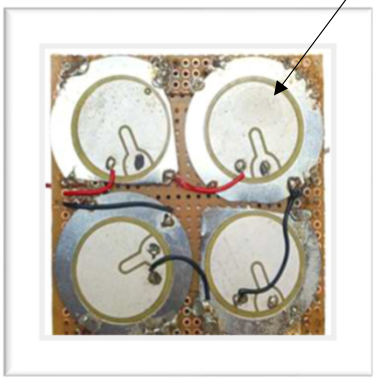
- To validate the performance of the energy harvesters, the device was adapted for a system that monitors the transportation of artworks. It achieves this by converting radiation and vibration from smart packages into energy for GPS tracking. Stopper systems were introduced to make the setup nonlinear, enhancing its responsiveness across a broader range of vibration frequencies.



The GPS board and battery on the upper side

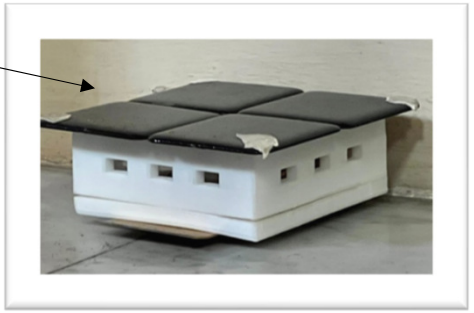


4 piezo elements on the underside



Measurements performed in laboratory

The complete node



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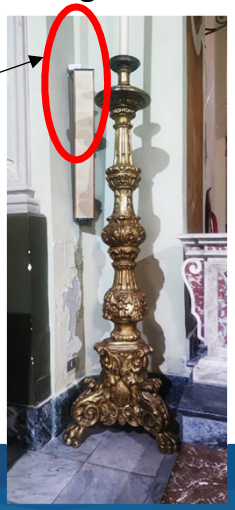
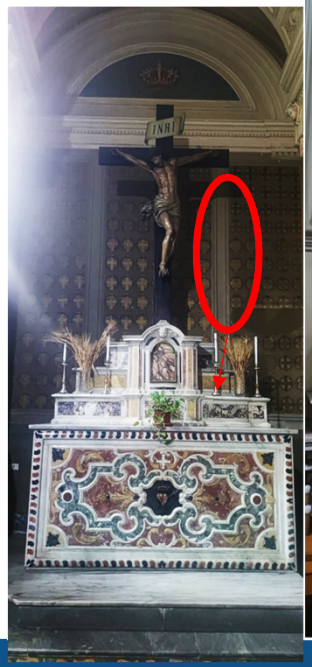
- An initial validation was conducted at the Castello Ursino Museum to monitor temperature and relative humidity. This work is ongoing, with further validation now taking place inside the San Biagio Church in Catania. An extensive study will follow to comprehensively evaluate the sensing capabilities and energy-harvesting features."

San Biagio Church, Catania, Italy

Nodes





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San Biagio Church, Catania, Italy

The campaign at San Biagio Church began with all four sensors initialized under identical conditions, including battery charge. Initial results indicated that the systems with the energy harvester consistently maintained higher charge levels.

The charge level of the sensor labeled as SB4, the one with the complete harvester systems, which sometimes even increases its charge over time.

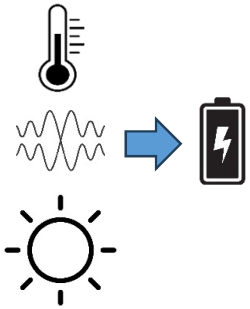
NODE	24/11/2023	05/01/2024	23/02/2024	27/10/2024
SB1	100%	80%	80%	60%
SB2	100%	80%	80%	60%
SB3	100%	80%	80%	60%
SB4	100%	80%	100%	80%

Power generation

$$P_{TEG} \simeq \frac{(N_T \cdot S \cdot \Delta T)^2}{4R_i}$$

$$P_{PIEZO} = \frac{m\zeta_e A^2}{4\omega_n(\zeta_m + \zeta_e)^2}$$

$$P_{SOLAR} = \left[\frac{N_s \cdot n_I \cdot K \cdot T_C}{q} ln\left(\frac{\alpha \cdot P_m}{I_0} + 1\right)\right]^2 \Big/ R$$



MAXIMUM POWER IN TEST RESULTS

Type of harvester	Condition	Power
PIEZO	ω_n 880 rad/s A_{RMS} 13.7 mm/s² R 270 Ω	0.89 mW
TEG	ΔT=19 °C R 10 MΩ	0.09 µW
SOLAR	P_m 433 R 10 MΩ	4.3 µW

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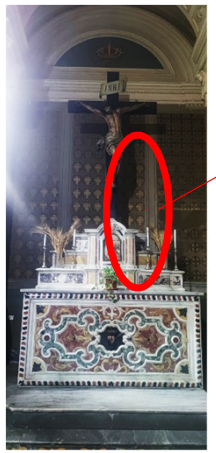
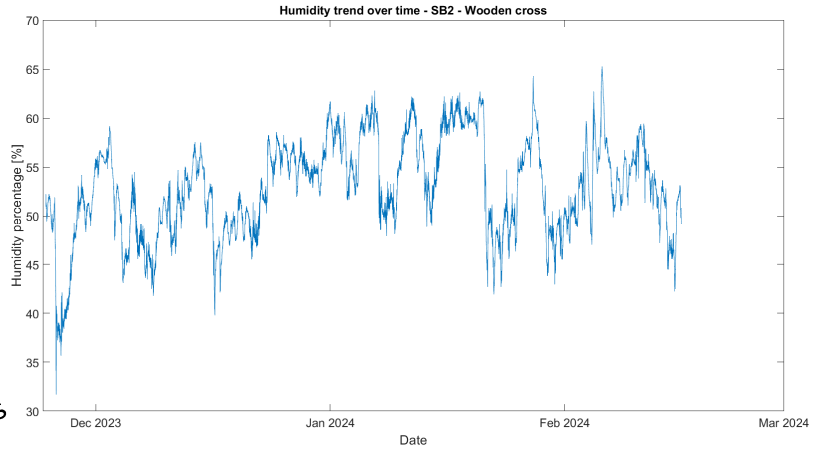
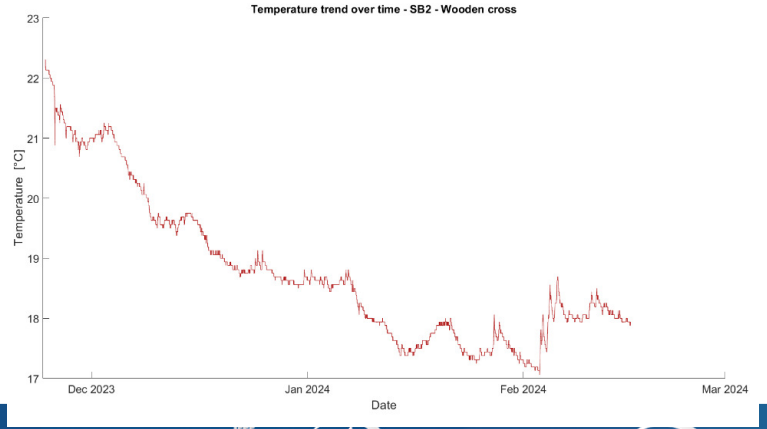
- Measurements have been recorded using a dedicated app, covering the period from December 2023 to February 2024. The work is ongoing, with plans for a more extensive measurement campaign lasting at least one year.

- The investigation into energy harvesting and its performance based on specific positions is ongoing. Currently, the node with the highest battery charge demonstrates the greatest capacity for energy recovery from radiation, temperature gradients, and vibrations. This observation aligns with theoretical predictions.



Preliminary results





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San Biagio Museum

Ongoing Activities:

1) An optimized node has been designed, built, and is currently undergoing characterization. This node includes 4 piezoelectric transducers, 4 radiation sensors, and 4 thermoelectric generators (TEGs) to increase harvested power.
2) Exhaustive, long-term microclimate monitoring is being conducted at the San Biagio Museum and St. Catherine's Church in Valletta, Malta.

St. Catherine's Church in Valletta, Malta

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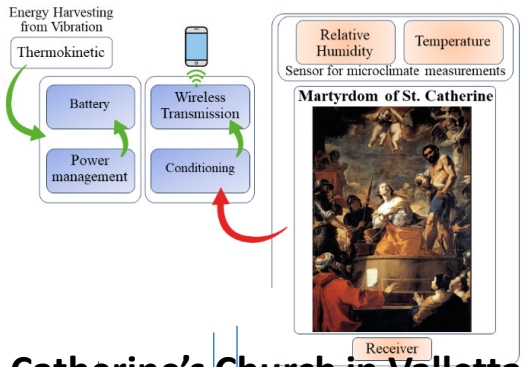
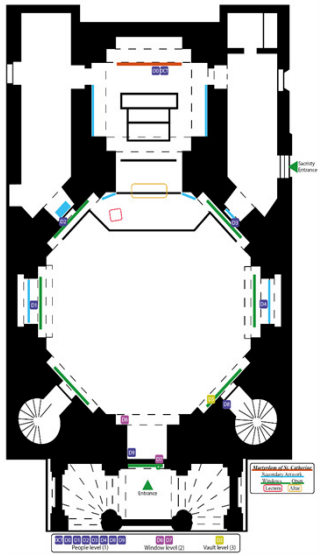
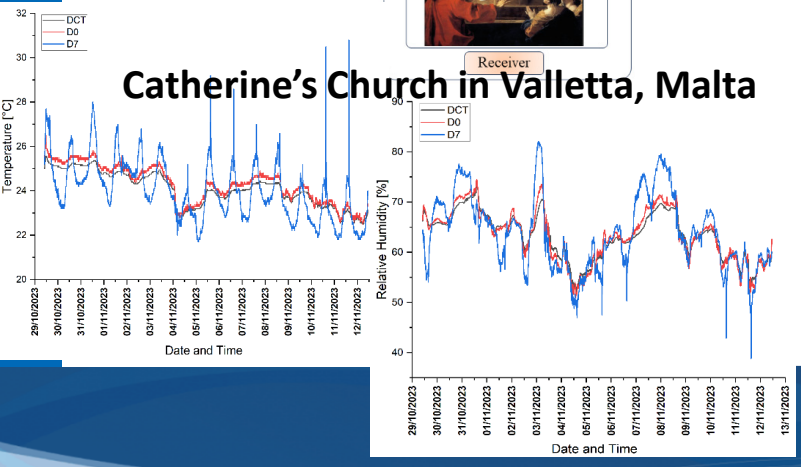




Catherine's Church in Valletta, Malta



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St. Catherine's Church in Valletta, Malta

Sintesi delle ricadute del progetto

- Budget economico: 115900000 Euro
- Mesi uomo impegnati 3 mesi/anno
- Ruolo nel progetto (spoke leader nazionale, locale, partecipante, WP leader, task leader etc.): partecipante e responsabile WP3-UNICT affiliato CNR
- Strutture/attrezzature acquistate nell'ambito del progetto: Rohde & Schwarz MXO44-2410; Rugosimetro a induttanza e a ultrasuoni.
- Nuovo personale arruolato: 2 Dottorandi 39° e 40° ciclo, Dr. Giuliano Salerno, Dr. Amine Karoui

Grazie