Wepop Newsletter

March 2025

PI's Interview – Prof. Marco Arnesano, full Professor e-Campus University

Let's meet the Principal Investigator of the project.

1. Which is the main objective of the project and which is the expected impact?

*WEPOP aims at demonstrating that **personal comfort models** are viable in real life thanks to the exploitation of emerging technologies such as wearables, artificial intelligence, and digital twin. We strongly believe that using personal comfort models can **improve life quality** in buildings with a more efficient use of energy.*

2. Which is the most innovative element of the project?

*WEPOP integrates a set of innovative elements that can be composed in different ways to fit the needs of numerous use cases. We tackle the challenge from different perspectives always thinking that the one-fits-all solution is impossible in real life. So, we are going to build an **operating platform** that can be used from the creation to the application of personalized comfort models.*

3. In a few words, tell us why WEPOP is different from the other projects.

*Most of the projects are focused on the development of a model based on a specific dataset. Instead, we are focused on the whole picture to make technologies applicable for personal comfort modelling. In this way other initiatives can exploit WEPOP outcomes to increase the adoption of personal comfort. In fact, we are creating a **multisensing platform** together with new sensing techniques that can be used, in future, for the creation of models in any context. Within the project time we will demonstrate how it can be used and the benefit that can derive from that.*

4. Until now, which has been the greatest challenge you had to face?

*Well, with such an ambitious idea, we are facing several challenges. For example, the **interoperability** with different commercial solutions and prototypes requires a huge effort. Off-the-shelf systems*

sometimes are not open or make use of proprietary communication protocols. Concerning the wearables, the ***measurement accuracy*** *could be not high enough, so dedicated signal processing techniques are required. Finally, we are conducting large experimental campaigns, requiring a strong commitment from the WEPOP team.*

5. Tell us what in your opinion makes a project successful.

Engagement is the keyword for projects success. In the case of projects with an important activity of technology integration, as WEPOP is, it is really important that the team has a common vision and each member knows exactly her/his role in the global picture and knows that her/his role is fundamental for the success of the project.

6. Are there active collaborations with enterprises that pave the way to a possible follow-up of

WEPOP after its end?

Yes, of course. WEPOP is creating a platform that integrates sensors for environmental and physiological measurements, personal comfort systems, and HVAC systems. Even if we are developing some prototypes, to make the go-to-market path shorter we are collaborating with companies that are supporting the integration of their solutions with our platform. We are in contact with Versuni (former Philips) for the integration of local heating and ventilation devices. Also, one of our supporter is AWEAR, a start-up company born in the U.S.A. that is developing an innovative wearable device for real-time EEG measurements.

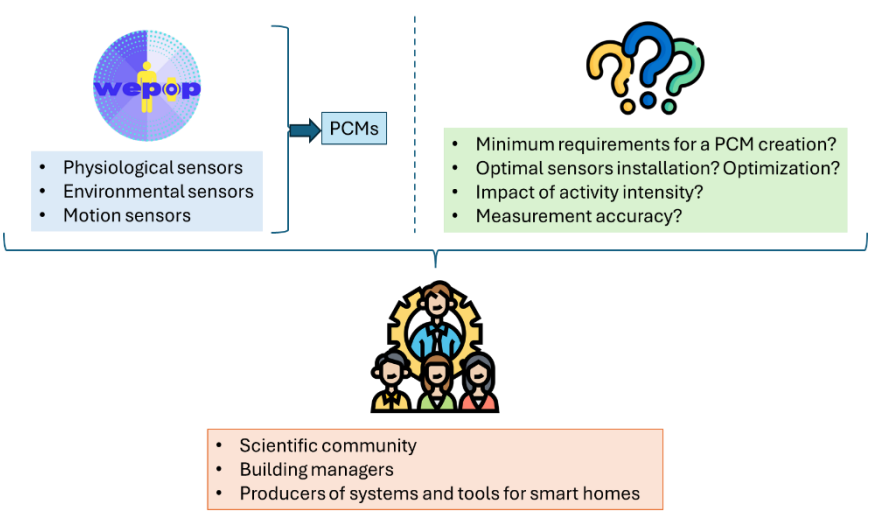
7. What do you advise to the researchers in this field?

*If I look at the WEPOP pathway, the first word that comes to my mind is "****multidisciplinarity****". Researchers working in the field of indoor comfort must use a multidisciplinary approach because comfort is no more just a "temperature problem". It is a complex topic that needs to be investigated with a multifaceted competence, ranging from building physics to physiology and data science.*

Main Research Questions & Target Groups

The project activities are focused on some specific research questions, driving both the experimental campaigns design and the data analysis methodologies.

First, WEPOP intends to investigate the **minimum requirements to create a personalized comfort model** (PCM), selecting those physiological and personal features more correlated to comfort.



Moreover, the **optimal architecture of sensors** placement is investigated in order to define an installation scheme within indoor environments that can provide good quality data reliably mirroring the occupants' comfort perception.

Also, the **impact of physical activity**, evaluated through motion sensors, is relevant to improve the PCMs performance. In addition, a threshold on a movement-related signal (e.g., accelerometric signal) can be defined to select/discard good/bad quality physiological signal portions. This can ease the correction of physiological signals on the basis of the activity being performed. In this context, not only wearable movement sensors (e.g., accelerometer embedded in a smartwatch) can be exploited, but also sensors installed in the room. Just as an example, ultrasound sensors could be placed in a working station to identify the activities performed and, hence, get an insight into the subject's energy consumption affecting the perceived comfort level.

Finally, WEPOP wants to analyze the **measurement accuracy** in the determination of individual multi-domain comfort status through the acquisition of physiological signals, during common office activities. Hence, WEPOP aims to predict personalized comfort (in terms of thermal, acoustic, visual, and air quality domains) through the analysis of multidomain data (e.g., electrodermal activity – EDA signals, PPG signals, and electroencephalographic – EEG signals) collected through wearable devices. These can be both commercial and ad-hoc prototypes designed to maximize signal quality (e.g., through the adjustment of the contact pressure). The correlation between the subject's comfort preference and different quantities (e.g., activity level and type, emotional state, individual characteristics, etc.), which together can impact on the subjective physiological response towards a certain indoor environment, is investigated.

The results are of interest not only for the scientific community, but also to building managers and producers of systems and tools for smart houses. Today, personalized comfort is more and more investigated and can really contribute to the optimization of both occupants' well-being and building energy consumption.

First Test Campaign – Introduction & Setup

The WEPOP vision is built on a multi-modal sensing architecture that feeds, almost real-time, a unique platform dedicated to data collection, Personal Comfort Model development, and Personalized Environmental Comfort Systems management. This complex infrastructure requires progressive testing to ensure technological feasibility and establish a proper data processing pipeline. To this aim, experimental campaigns are conducted in a controlled laboratory environment: the NEXT.ROOM, the human comfort testing facility of the Environmental Applied Physic LABoratory, University of Perugia. The NEXT.ROOM (4x4x2.7 m) allows for precise control of multi-domain environmental boundaries, ensuring consistency in participant exposure while minimizing fluctuations. This setup enables researchers to study inter-individual differences in observed response variability. Moreover, the controlled laboratory environment gives the chance to test novel sensing setup, including wearables, as in the scope of WEPOP. However, laboratory studies often lack realism, but a well-defined protocol can mitigate this by engaging participants in activities that simulate daily tasks.

The first WEPOP campaign simulated office-like activities under slightly warm and slightly cool conditions. Conducted in summer 2024, the study used a within-subject design, requiring participants to complete tests in both thermal environments, i.e., operative temperature of 22 °C and 30 °C for the cool and warm scenario, respectively. Since office spaces are typically shared, each test session included two participants seated opposite each other at PC stations. The innovative measurement of the campaign are the integration in the NEXT.ROOM of ultrasound sensors, in the ceiling and in the desk, to monitor office activities. In addition, participants wore a Muse headband for key EEG channel collection and an Emotibit device on the wrist, to measure ECG and EDA signals. During a single test, participants performed a sequence of tasks including individual, interactive, and conflicting activities.

At the end of each task, participants fulfilled a set of questions aimed at catching their perception of the environment in a right-here-right-now format. A total of 24 participants (10 females) completed both test sessions. Some technical challenges arose, particularly regarding multi-modal data synchronization. However, these were successfully addressed with the release of a second version of the WEPOP Platform, which supported the second experimental campaign, recently concluded in winter 2025.

Innovation highlights #1 - Ultrasound for Activity Measurement

A key focus of our project is leveraging **ultrasound technology** to monitor activities in office environments while ensuring user privacy. This innovative approach enables **multidomain sensing**, where data from various sources are combined to enhance the understanding of workspace dynamics.

Activity recognition is a crucial component, as physical movements directly influence metabolic rate—a key parameter in developing **personalized comfort models**. Traditional monitoring systems often rely on cameras or wearable devices, raising concerns about privacy and requiring extensive infrastructure. Our ultrasound-based solution addresses these challenges by offering a **non-intrusive, cost-effective alternative** that seamlessly integrates into office environments.

Our measurement process involves **advanced data analysis, machine learning (ML), and artificial intelligence (AI) algorithms** to accurately classify different activities. By processing ultrasound distances, the system detects motion patterns without capturing identifiable personal data. This ensures that user privacy is maintained while still providing valuable insights for workspace optimization and energy-efficient environmental control.

With this technology, smarter and more adaptive office spaces can be created, where comfort settings dynamically adjust based on real-time activity recognition. This not only improves the user experience, but also contributes to energy conservation, making workspaces more sustainable.

Ciuffreda, I., Cosoli, G., Revel, G. M., Arnesano, M., & Casaccia, S. (2024, June). A Non-Intrusive Ultrasound-Based Sensing Technique for Activity Detection: Proof of Concept Towards Optimized Personalized Comfort. In *2024 IEEE International Workshop on Metrology for Living Environment (MetroLivEnv)* (pp. 16-21). IEEE.

Innovation highlights #2 – Wearable device

WEPOP activities, aiming at domestic well-being in a holistic prospective, include the monitoring, through a wearable device, of the main physiological parameters that can describe the physical well-being of a subject. The reading of these parameters, and their interpretation which will be performed through advanced analysis techniques, can be used to adopt targeted changes to the domestic environmental parameters and adapt them to the personal needs. For this step, it is crucial to keep high the quality of the signal (i.e. PPG) as it may depends on the specific subject's characteristics and from environmental parameters. This would allow both to achieve accurate cardiovascular parameters and to make effective predictions in the environmental needs to achieve optimal personal comfort.
To achieve this goal, it is essential to identify any possible influencing parameter that could harm the quality of the signal and adopt mitigation and corrective strategies to limit them.

Thus, the innovation of the wrist-worn wearable device that WEPOP will design lies on its capability to "adapt" itself to the specific biophysical characteristics of each subject to improve the accuracy of the acquisitions.
Therefore, a first experimental campaign was performed on 25 subjects to evaluate how the variation of contact pressure influences the quality of the signal for each subject and how it should be kept for different intensities of physical activity.
An additional experimental campaign performed on 25 subjects, was aimed at studying how external temperature (ranging from 15 to 35 °C), which cause vasoconstriction and vasodilation phenomena, influences the PPG signal and the extraction of the physiological parameters of interest.
Both studies were fundamental for the design of a wearable system able to regulate contact pressure based on the specific subject's characteristics and on the external conditions. The operating logic, in fact, will be developed on the results of the first two studies.
A third experimental campaign will be conducted to assess the metrological performance of the PPG-based prototype, which will integrate the automatic contact pressure control.

Dissemination activities - website

Through dissemination activities, Wepoppers aim to share the research results with a wide audience, ensuring that the benefits of comfort measurements are accessible to all sectors.

These activities include participation in conferences, events, and the publication of research papers, which will help spread awareness and foster further development in the field.

Next events:

Wepop will be showcased at the **IEEE Metrology for Living Environment (Metrolivenv) conference**, which will take place in Venice from June 11th to 13th. During this event, a special session, titled *"Measurement systems and strategies for the assessment of personalized comfort in the built environment: towards human-centric and resilient building management solutions"*, dedicated to the thematic research aspects of the project has been organized.

Publications:

Arnesano, M. (2024, June). Development and Application of EEG Signal Pattern Analysis and Artificial Neural Network for Indoor Comfort Measurement. In *2024 IEEE International Workshop on Metrology for Living Environment (MetroLivEnv)* (pp. 11-15). IEEE.

Ciuffreda, I., Cosoli, G., Revel, G. M., Arnesano, M., & Casaccia, S. (2024, June). A Non-Intrusive Ultrasound-Based Sensing Technique for Activity Detection: Proof of Concept Towards Optimized Personalized Comfort. In *2024 IEEE International Workshop on Metrology for Living Environment (MetroLivEnv)* (pp. 16-21). IEEE.

Scardulla, F., Riggi, C., Diana, G., & D'Acquisto, L. (2024, June). Preliminary Analisys on the Effect of Skin Temperature on Photoplethysmographic Signal. In *2024 IEEE International Workshop on Metrology for Living Environment (MetroLivEnv)* (pp. 6-10). IEEE.

Gnecco, V. M., Chiucchiù, A., Pigliautile, I., Mansi, S. A., Cosoli, G., Arnesano, M., & Pisello, A. L. (2024, June). Definition of the Acclimatation Time in Test Room Experiments Through Objective Physiological Indicators. In *2024 IEEE International Workshop on Metrology for Living Environment (MetroLivEnv)* (pp. 1-5). IEEE.

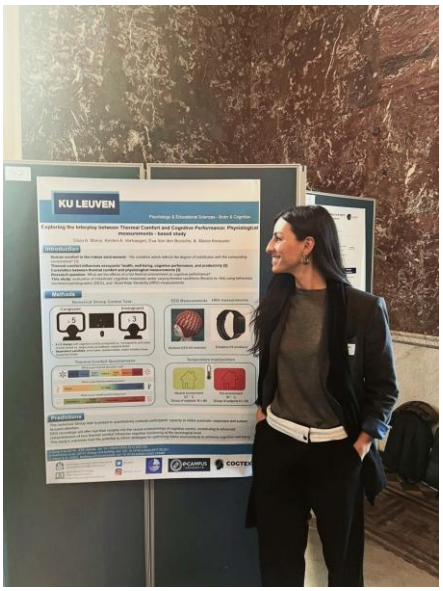
Past events:

September 2024: Wepop has been presented at the 8th National Forum on Measurement 2024 (Forum Nazionale delle Misure) in San Vincenzo (Tuscany) by Prof. Francesco Scardulla with a work titled "Effect of Skin Temperature on Photoplethysmographic Signal" and by Prof. Sara Casaccia with a poster titled "Activity Detection of People in Indoor Environment: A Measurement System Based on Non-Intrusive Ultrasound Sensors and AI Techniques" .

July 2024: WEPOP has been presented at the Toronto Metropolitan University during the Summer School organized by the International Association of Building Physics with a work titled "Describing acclimatation time in test room experiments: improving human-centric comfort assessment procedures".

June 12-14 2024: WEPOP has been presented at the IEEE WORKSHOP ON METROLOGY FOR LIVING ENVIRONMENT 2024 (Crete – Greece) with a Special Session titled "Measurement of physiological and environmental parameters: towards optimized personalized comfort and automated HVAC and light regulation in the built environment".

November 24th 2023: WEPOP was presented at NeuroCog 2023 in Brussels.



Partners:

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