SYMPHONY newsletter 1

Jan-2025

This first issues includes:

- Introduction to the project from CNRS
- Review of project use cases by Senseair
- Intro to machine learning at AUTH.

More information is available on the project website https://symphonyproject.eu

This photo shows one of the container-sized biogas plants from Bert, which can be utilised for the application scenarios in the SYMPHONY use cases.

Consortium

cnrs, Aristotle University of Thessaloniki, ST, Vivid Components, Δήμος Νότιας Λευκωσίας-Ιδαλίου, Resolute Photonics, bert, Cyric, KTH Vetenskap och Konst, microTEC Gesellschaft für Mikrotechnologie mbH, CSIC Consejo Superior de Investigaciones Científicas, Senseair

Please join the SYMPHONY LinkedIn group to keep up with project updates!

https://www.linkedin.com/company/symphony-project

Coordinator	Carlos Ramos	Université Paris Saclay - CNRS	carlos.ramos@c2n.upsaclay.fr
Admin	Bruce Napier	Vivid Components Germany	bruce@vividcomponents.co.uk

Funded by the European Union

This project has received funding from Horizon Europe, the European Union's Framework Programme for Research and Innovation, under Grant Agreement No. 101135523 (SYMPHONY). Funded by the European Union. Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union. The European Union cannot be held responsible for them.

Welcome to SYMPHONY!

An introduction to the SYMPHONY project from project Coordinator Carlos Ramos; C2N, CNRS (Paris, France).

Tackling air pollution and biogas production with cutting-edge sensor technology

Air pollution remains one of Europe's most pressing health and environmental challenges, contributing to nearly half a million premature deaths every year. Meanwhile, biogas production has emerged as a key player in reducing greenhouse gas emissions and diversifying Europe's energy sources. However, both air quality control and biogas production require significant advances in sensor technology.

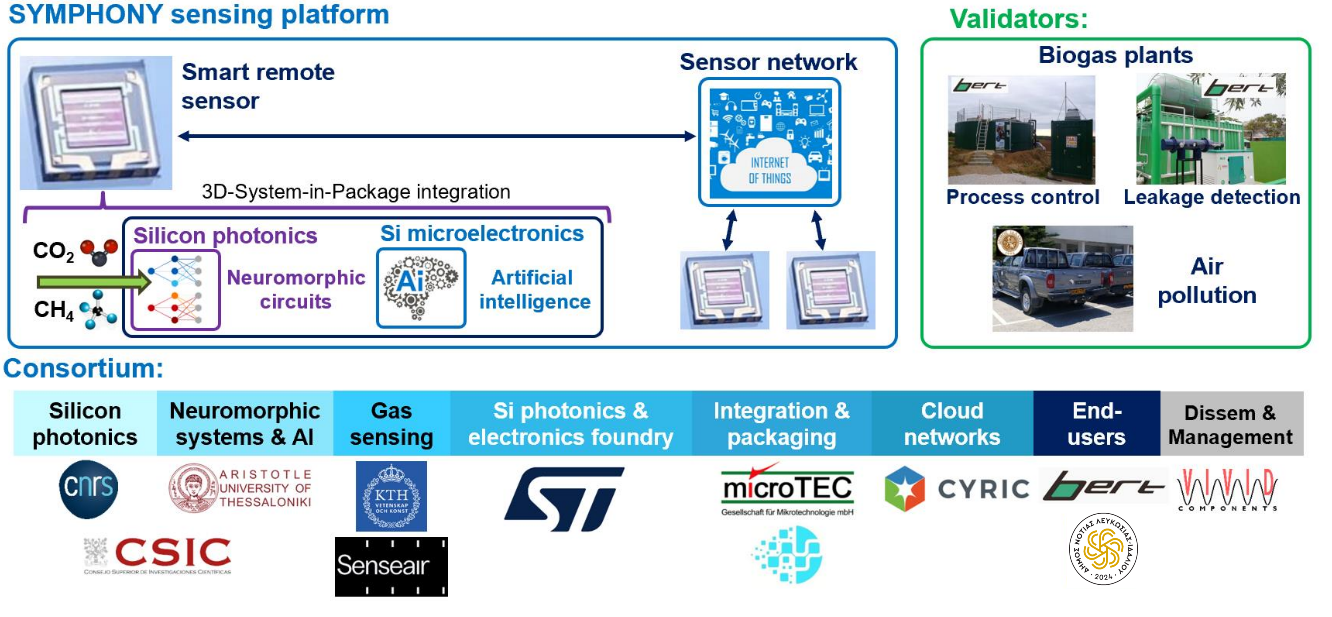
Enter the SYMPHONY project, launched in Apr-2024, which aims to revolutionise sensing technology for cleaner air and sustainable energy. SYMPHONY is developing a next-generation platform of low-cost, portable, cloud-connected smart sensors. These sensors will enable precise, multi-gas detection for a wide range of applications including air pollution monitoring, industrial process control and safety.

What makes SYMPHONY unique?

• *Smart sensors:* Designed to detect key greenhouse gases like CO_2, CH_4, and NO_2, SYMPHONY's sensors target emissions from biogas production and urban pollution hotspots.

• *Cutting-edge technology:* The platform combines silicon photonics, neuromorphic circuits, AI and ultra-low power microelectronics to deliver real-time data and predictions.

• *Wide application:* Validation is planned in three key scenarios: urban air monitoring in Cyprus, biogas plant process control and leakage detection across Europe.



The SYMPHONY sensing platform: a cloud-connected network of smart sensors harnessing silicon photonics, silicon microelectronics and AI to provide low-cost miniaturised multi-target detection for applications in environmental monitoring, industrial process control and safety.

A European Collaboration

The SYMPHONY project brings together an exceptional consortium of experts from seven European countries, including universities, research institutes, companies, and end-users. Covering the entire innovation chain—from photonics and microelectronics to gas sensing and IoT—this team is driving the development of a sensing platform for a more sustainable and healthier future.

Stay tuned as SYMPHONY pioneers the next leap in sensor technology to address air pollution and accelerate the green energy transition!

For more information please contact carlos.ramos@c2n.upsaclay.fr

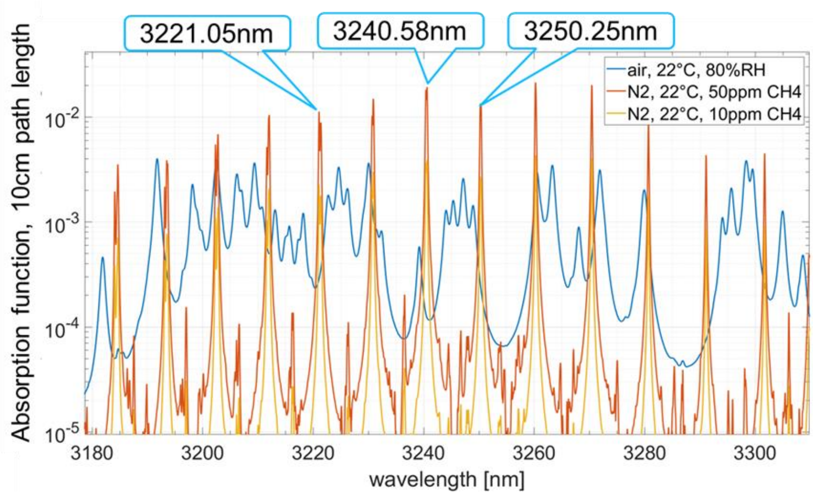
Use cases in SYMPHONY

Right from the SYMPHONY Kick-off meeting at CNRS in Paris (04-Apr-2024), Senseair has taken the lead in defining the use case specifications. It interviewed the two end users, South Nicosia-Idalion Municipality (Cyprus) and Bert Energy (Germany) to learn more about their specific needs and demands for a successful deployment of the envisioned gas sensing prototypes. The first use case is pollution monitoring at strategic selected locations in South Nicosia-Idalion, ensuring an effective area coverage and mapping of air quality and thus providing a solid and rich data set for the municipality to validate its current measures for reducing pollution and improving air quality.

Left: A map of Cyprus showing the location of South-Nicosia Idalion Municipality, one of the end users in SYMPHONY.
Right: A larger scale map of South Nicosia-Idalion with two locations for the deployment of the gas sensing prototypes.

Detailed discussions with Bert Energy were held on the second use case to extract and cover all relevant considerations to realise a user-friendly leakage detection system for greenhouse gas emission such as methane and carbon dioxide at small-scale biogas plants, and to extend this monitoring system with dedicated sensing equipment for establishing a capable process control system based on the observation of the process gases with the biogas reactor.

Following a classical top-down approach in system engineering and gathering all relevant operational conditions, including specific functional requirements, has facilitated Senseair's objective to conduct detailed simulations on gas compositions for extracting applicable absorption spectra of the target gases and thus defining critical boundary conditions for a solid design of the photonic components, such as the sensing waveguide and the spatial heterodyne Fourier transform spectrometer. The graph below depicts such an application-specific absorption spectrum in the one of the selected regions of interest within the mid-IR wavelength range. Multiple unique absorption peaks have been identified and highlighted in a mixture of 10 ppm and 50 ppm methane, respectively, using a background spectrum of air with a relative humidity of 80 %. Selecting such an absorption peak and its specific shape provides the basis for the design of the photonic integrated circuit and to evolve SYMPHONYs' highly integrated gas sensing system towards a large-scale deployment solution for pollution monitoring and leakage detection in the oil and gas industry.



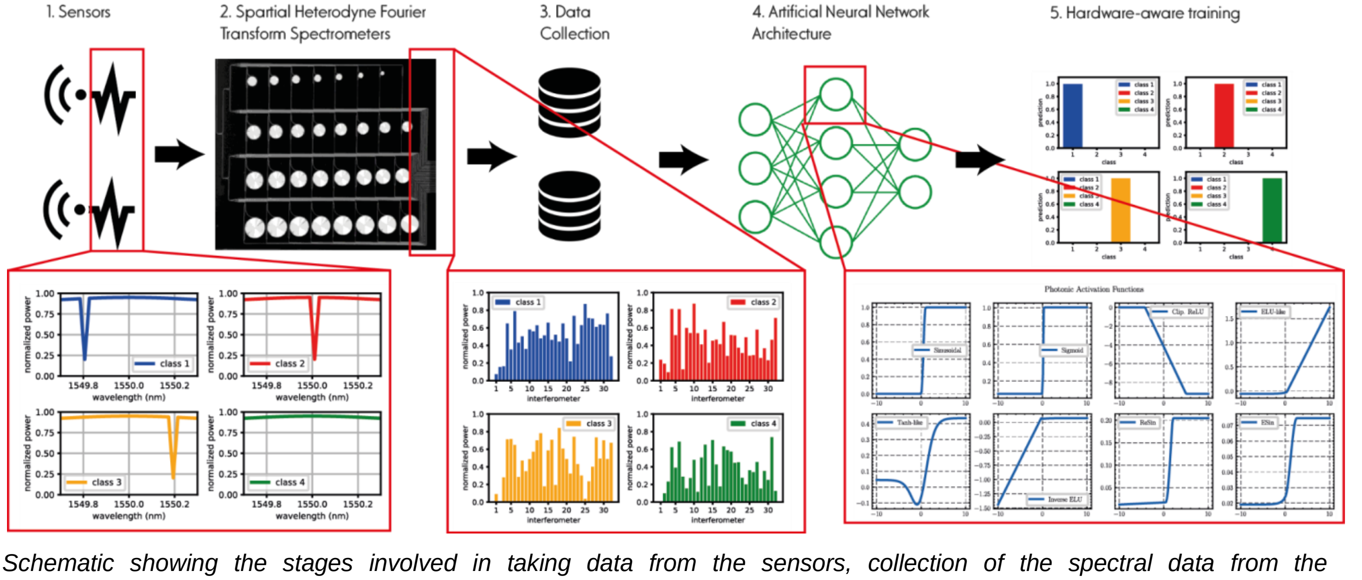
Absorption peaks in the mid-IR wavelength range in mixtures of 10 ppm and 50 ppm methane using a background spectrum of air with a relative humidity of 80 %. Some key peaks of interest are highlighted in the blue boxes above the graph.

For more information please contact stephan.schroder@senseair.com

Edge and cloud-based AI for gas analysis

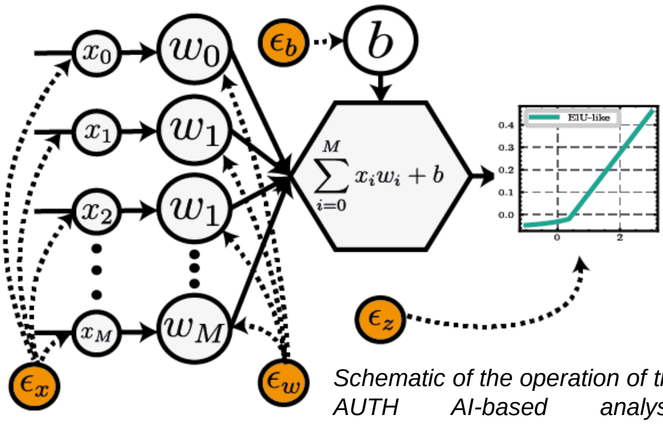
ARISTOTLE UNIVERSITY OF THESSALONIKI

Aristotle University of Thessaloniki (AUTH) has developed the appropriate pipeline to train the deep learning (DL) algorithms that will be integrated on the hardware accelerators, including both the electronic processor (provided by ST Microelectronics) and the optical chip designed by AUTH. The pipeline includes a near-infrared (NIR) sensor that feeds the



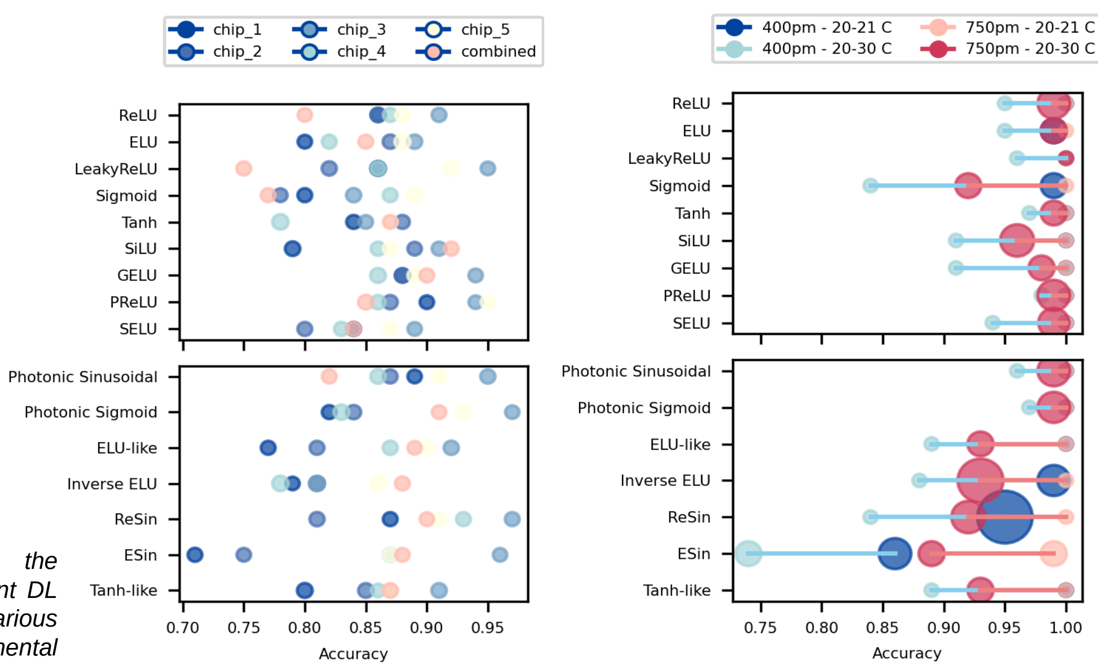
Schematic showing the stages involved in taking data from the sensors, collection of the spectral data from the spectrometers and the application of AI to derive the gas concentrations.

spatial heterodyne Fourier transform (SHFT) component with the acquired spectrometers, which includes the information regarding the absorption of gases in the atmosphere. In turn, data is collected from the SHFT response, which includes the discrete gas absorption features, and these are used for training the algorithms. Since the response of the SHFT is highly dependent on the environmental temperature, data collection was performed in reference to the temperature range and different experimental iterations of the chip. The extracted datasets also depend on fabrication errors in the SHFT components, leading to intrinsic imperfections in the data. Finally, the dataset is used to train the neural networks taking into account the various available transfer functions and levels of quantisation noise. AUTH has developed the theoretical framework and designed the appropriate models that can meet the challenging requirements of gas detection in both edge and cloud. Such challenges include compensation of the fabrication imperfections and noise sources that intrinsically exist in the sensor device, SHFT module and DL accelerator. To this end, AUTH developed and evaluated noise resilient methodologies for training the DL models that take into account the noise impairments during training making the DL models more robust during the deployment.



Schematic of the operation of the AUTH AI-based analysis methodology.

Such methodologies range from quantisation-aware to optics-informed training that allows incorporatoration of the constraints of the hardware in the training process. Preliminary results acquired from precise simulations of the available hardware, which are based on the extensive characterisation of the devices, have shown very positive results. The numerical results indicate that the applied methodologies will allow AUTH to deploy the DL algorithms even in significantly lower arithmetic precision as well as in highly constrained architectures.



Schematic showing the assessment of different DL methods using various chips and environmental conditions.

For more information please contact Manos Kirtas eakirtas@csd.auth.gr