TELECOM Paris

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Institut Mines-Télécom

Palaiseau, July 23, 2025

PhD Scholarship Opportunity

«Event Recognition and Classification in Distributed Acoustic Sensing over Optical Fiber Networks »

Context

Infrastructure monitoring relies on the collection and use of data extracted by many sensors delivering information on road traffic, detection of human presence and many events affecting the infrastructure (water and gas distribution networks, transports, etc.). The current approach to collect this information is to deploy a multitude of discrete and dedicated sensors. This deployment has a high logistical cost (installation, energy supply, maintenance). Urban DAS (Distributed Acoustic Sensing) using optical fiber is a new way to sense the environment [1]. Telecom fiber optic networks already crisscross current cities: the use of this available infrastructure for the purposes of capturing, locating and identifying vibration events is a very attractive approach.
Characterization and localization of vibration events with the highest possible accuracy, followed by their identification using signal processing algorithms and artificial intelligence, paves the way for the provision of valuable data for a multitude of applications (road/rail traffic supervision [2-3], security, intrusion detection, seismic [4]…).
This project aims to benefit from the deployed optical transmission fiber cables as a multitude of passive sensors in order to make possible the telemetry (detection-localization-identification) of a set of vibratory phenomena. Its implementation however faces three major requirements: transparent integration (no impact on the quality of service of the telecom network), guarantee of an extreme sensitivity to vibratory phenomena affecting the fiber and post-processing to allow an optimal discrimination of the detected phenomena.

Approach and goals

DAS relies on the existence of distributed Rayleigh backscattering centers in the fiber core, an inherent impairment in optical fibers. When an interrogator sends an optical signal (probe signal) generated from a highly coherent laser source through a fiber end, small fractions of this signal are randomly scattered back towards the interrogator. Distributed capture of vibrations by an optical fiber was suggested as early as 1977 [5-6] and the possibility of their detection through changes in backscattered Rayleigh intensity was shown in the 1990s [7]. This work led to the first commercial systems for geological applications (seismic detection, monitoring of oil and gas wells) and structural monitoring in the early 2000s, with limited

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sensitivity and bandwidth. There is, however, a much larger potential for DAS in the field of monitoring and security, up to the recognition of multiple acoustic signatures [8-11]. To reach these goals, it is necessary to consider, beyond the optical intensity alone, the temporal evolution of other physical quantities (optical phase and state of polarization for instance), which requires an interferometric detection after injecting a probe signal into the fiber, most often through a series of optical pulses [12-15].

In this thesis, we want to focus on defining the best representation of the detected data (intensity-phase-SOP) to recognize vibration events through machine-learning (ML) algorithms by comparing various projection spaces before feeding the compressed sensed data to a classifier. Dr. Élie Awwad who has a strong background in DAS and Dr. Ekhiñe Irurozki who has a strong background in ML will supervise the thesis. We plan to perform the following three tasks:

Pre-processing data/ Data compression

Pre-processing will mainly aim at de-noising and compressing captured data [16]. Compression is key as large volumes of data will be collected (almost one Terabyte per hour of data for a meter-scale spatial resolution over 50 km fiber cable and a 4 kHz sampling). We will consider various representation spaces of data such as Stokes parameters for SOP or time-frequency decomposition of data using wavelet theory. We will also study mechanical coupling models through the fiber cable to capture the strain transfer between the environment and the cable [17].

Feature extraction and analysis

Following pre-processing, we will focus on feature extraction. We will define and extract features using several approaches such as cepstrum analysis [18] used for vibration and speech signals, and separation of various signal patterns [19] that can achieve a good complexity-accuracy trade-off when describing complex events or interactions between several events. We will consider the evaluation of dissimilarities between current statistical features of measured parameters and past features as a potential event identification method [20]. We will study different approaches and apply them over available online DAS databases for relevant applications [21] as well as on captured data from our lab setup and in-situ measurements.

Event identification

Finally, we will feed the extracted features to a classifier for event identification and localization. One interesting application beyond event recognition is the estimation of its geographic location using the multiple strains that the event creates in a single or multiple fiber cables. We shall adapt time series, functional and signal classification [22] for the former and physics-informed signal processing neural networks [23] for the latter. We will study the performance of various classifiers such as artificial neural networks, random forests or deep learning approaches, as well as the benefits from using transfer and reinforcement learning [24,25].

The developed schemes will be validated through: 1) extensive simulation work at Télécom Paris, 2) lab measurements on the sensing platform at Télécom Paris and using commercial DAS interrogators, and 3) field trials with end-users.

About the ANR 2024 SAFER project

SAFER for "Seamless Acoustic sensing over Fiber nEtwoRks" is a French project funded by the national research agency (ANR) through its generic call for proposals of 2024. It is coordinated by Élie Awwad from Télécom Paris and involves two partners: GTO team at Télécom Paris and Invisensing.io, a French start-up specialized in DAS products. SAFER is a four-year project that was launched in March 2025.

About our lab

The Information Processing and Communications Laboratory (LTCI) is Télécom Paris' in-house research laboratory (130 research professors and 250 PhD students, Postdocs and research engineers). The LTCI was created in 1982 and is known for its extensive coverage of topics in the field of information and communication technologies. The LTCI's core subject areas are computer science, networks, signal and image processing and digital communications.

Élie Awwad is a member of the Optical Telecommunications Group (GTO) that is home to the research programs of eight faculty members and a state-of-the-art laboratory on optical fiber transmission. GTO conducts advanced research in high-rate fiber-optic transmission, optical network architectures, novel lasers for communications, integrated photonics, and distributed optical fiber sensors. Ekhiñe Irurozki is a member of Signal, Statistics and Machine Learning (S2A) team that conducts advanced research in probabilistic modeling, statistics, optimization, (audio) signal processing, machine/deep-learning and computational linguistics.

Duration and Location

- Three-year grant starting from January 2026.
- Location:
  GTO team
  Télécom Paris, Institut Polytechnique de Paris,
  19 place Marguerite Perey, 91120 Palaiseau, France

Qualifications

- The candidate must have successfully finished an M2 program in Computer Science, Electrical Engineering, Optical Communications, Photonics, Signal Processing, Acoustics or related domains.
- Knowledge of digital signal processing algorithms is required. Knowledge of optical transmission systems and networks is desirable.
- Skills in DSP programming (through MATLAB or Python) are required.
- Strong interest for applied research.
- Ability to work in a multi-cultural environment and to supervise interns and/or M1/M2 students during projects

Contact

To apply, please send your CV, M1/M2 academic transcripts, motivation letter, and publication record (when applicable) to:

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