Deliverable

[D2.2: Deployment of Prototype Array]

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Summary

In November 2019, we carried out a pilot study in Bern, Switzerland, in collaboration with the SWITCH Foundation and Silixa Ltd. The purpose of this study was to test the feasibility of the use of DAS (Distributed Acoustic Sensing) technology for the purposes or urban seismic tomography, site characterisation, and potentially earthquake early warning. This short report details the experimental setup, initial data, and planned further work.

1. DAS Overview

DAS technology facilitates the use of standard fibre optic cables as dense seismic arrays, using interferometry to detect miniscule variations in strain along on the fibre. DAS allows this strain to be detected at regular intervals along the fibre (down to tens of centimetres), meaning that a single fibre may act as thousands of inline strain detectors.

This technology has the potential to be extremely useful for monitoring seismic activity in urban environments for two main reasons: (1) the deployment of an array of traditional seismometers in urban areas can be extremely difficult due to dense infrastructure; (2) telecommunication networks almost always contain dark fibres – currently unused fibres that are installed for future expansion of the network / in case other fibres fail. The locations of these fibres are usually well-mapped by the owners of the network. This means that it is possible to connect a DAS interrogator to the end of one of these dark fibres and create an instant urban seismic array, avoiding the need to install a likely sparse network of traditional seismometers.

2. Bern Experiment

In November 2019, we collected seismic data over a period of two weeks, using dark fibre beneath Bern, Switzerland. The layout consisted of 3 km of fibre in a T configuration (Figure 1a), with the light signal reflected at the far end of the cable and returned through a second fibre, giving 2 x the 3 km layout. Data was recorded with a 10 m gauge length, 2 m channel spacing and sampling rate of 200 Hz, producing ~1.5 TB of data. This installation was likely to detect ground motion primarily caused by traffic, as well as construction, large machinery, and subsurface installations that may be close to the fibre (e.g. water pipes).

While the layout of the cable was known, the locations of the individual fibre channels were not. Therefore, we carried out a tap test using sequences of 5 jumps on the pavement, matching measured GPS locations (Figure 1b) to the channel at which the jumps were seen (Figure 2). Using interpolation, this allowed for the assignment of all usable channels to a physical location, facilitating future spatial analysis of the data.

Figure 1: (a): The blue line shows the location of the fibre beneath Bern, Switzerland. The red cross indicates the position of the iDAS interrogator **(b):** The collected GPS points used for calibration of the fibre data with physical locations

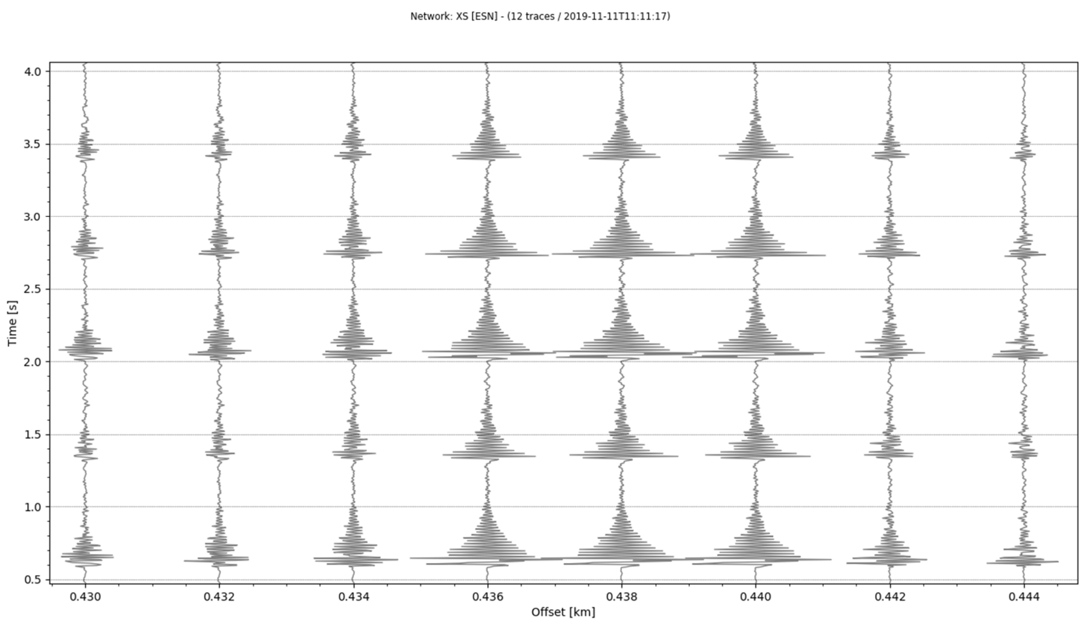

Figure 2: Example traces showing the visualisation of 5 consecutive jumps on the pavement, used to assign a fibre channel to a GPS location. Here, the jump was assigned to the channel at offset 0.438 km

3. Preliminary Data Overview

The data contain a very wide range of frequencies, from 100 Hz down to 10^{-4} Hz. This means that an enormous variety of signals are captured, from many cars to individual leaf blowers.

While visualising the data in real-time, we were able to observe the movement of vehicles and estimate their velocities by eye. We also saw the propagation of resulting seismic waves with much higher velocities (Figure 3), confirming that DAS is able to capture likely surface waves induced by anthropogenic activity. In one segment of cable (Figure 4), we simultaneously see slow-moving signals (~ 5km/h) while also seeing much faster-moving signals (~ 40 km/h). The faster signals are consistently in the same direction, as the fibre is situated in a conduit beneath the south-bound side of the road, meaning that vehicles are usually detected moving in the same direction. The slower signal is detected moving in both directions, suggesting that it may be caused by a larger vehicle. This may suggest slow-moving buses / trucks with faster moving cars, or possibly the detection of slow-moving trains approaching the nearby train station.

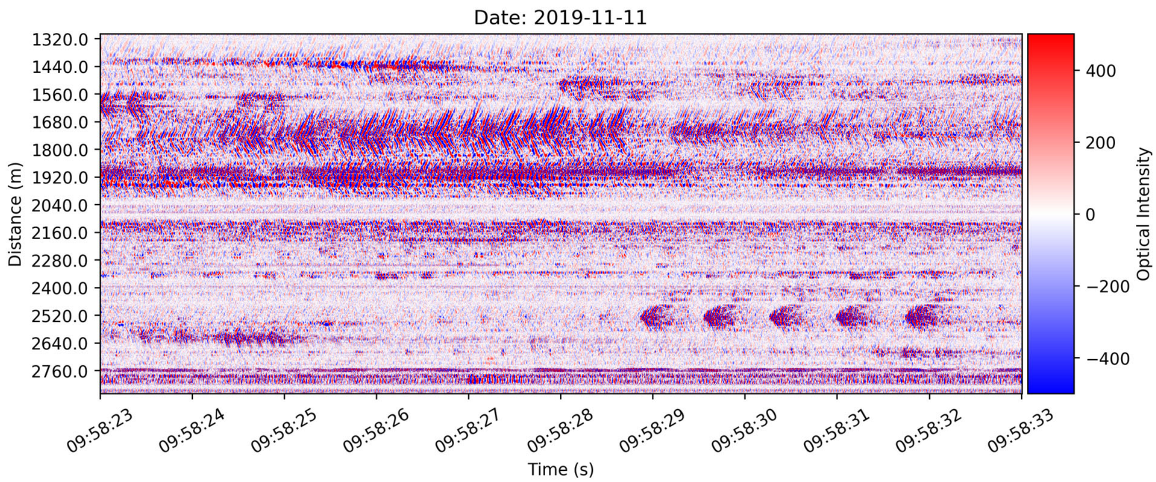

Figure 3: Raw data plot showing optical intensity. Colours indicate strain in the direction of the fibre. Around 1700 m we see what is likely to be a vehicle travelling along the road with a velocity of ~ 45 km/h. The steeply dipping waves emerging from the signal have a much greater velocity, and are likely to represent surface waves propagating through the shallow subsurface. We also see five tap test jumps at ~ 2520 m.

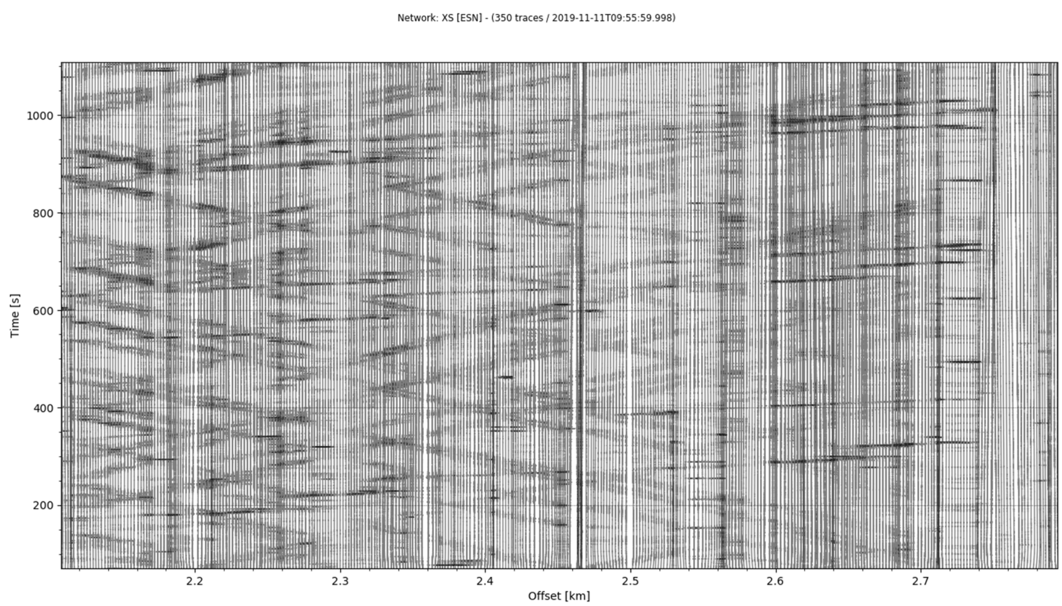

Figure 4: A 20-minute sample of data filtered between 20 and 50 Hz, showing multiple diagonal paths with velocities of ~5 km/h, as well as some velocities of ~40 km/h.

4. Further Work

Our current work is focused on visualising and classifying the full extent of the data, as well as exploring the application of existing noise correlation methods to this data set. We hope to obtain dispersion curves, and ultimately produce a tomographic model of the shallow subsurface of Bern, using anthropogenic noise measured with DAS. The outcome of this study will influence the application of this method to other areas, with the intention of understanding the subsurface of urban environments at risk of earthquakes and other natural hazards.