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Deliverable

Deliverable D2.4: Using DAS and geophone chain for imaging

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Summary

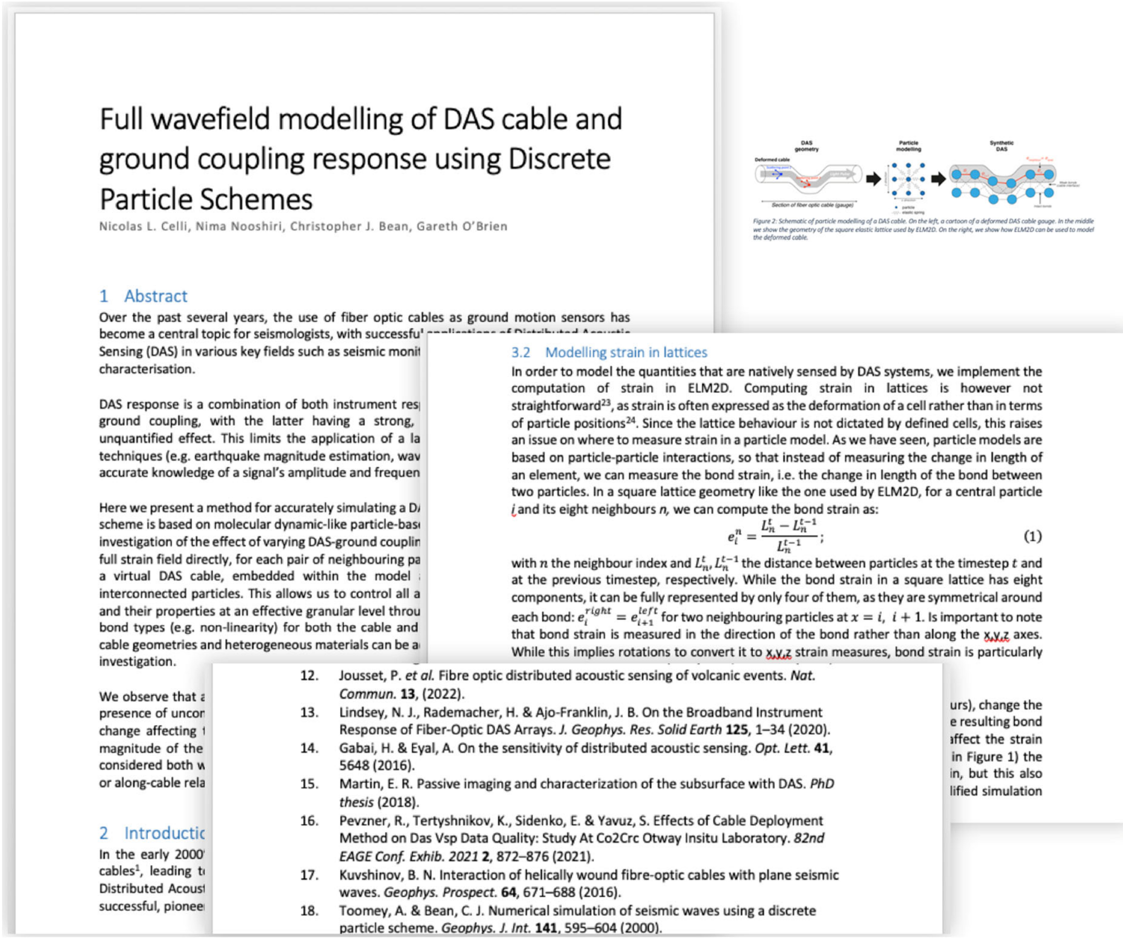
We developed a numerical solver to quantitatively simulate DAS records and used it to analyse what acquisition settings---e.g. ground-cable coupling, local site effects, presence of loose sediments around the cable---affect the response of a DAS cable. This tool allows the assessment of these effects and to separate them from the subtle signals targeted when imaging detailed structures both in synthetic models and real data.

1. Publication

We are in the advanced stages of the preparation of a publication on the topic, which we aim to submit at the end of January 2023. The delay until end of January is to allow us to work on a specific technical question (assessing the simulation results when increasing the resolution through finer model discretisation). The manuscript is largely written (see **Error! Reference source not found.**), and we submitted the following abstract for AGU 2022 where we will present the work that will go in the publication:

Full wavefield modelling of DAS cable and ground coupling response using Discrete Particle Schemes (Nicolas L. Celli, Nima Nooshiri, Christopher J. Bean, Gareth O'Brien)

Over the past several years, the use of fiber optic cables as ground motion sensors has become a central topic for seismologists, with successful applications of Distributed Acoustic Sensing (DAS) in various key fields such as seismic monitoring, structural imaging and source characterisation. DAS response is a combination of both instrument response (DAS interrogator) and cable- ground coupling, with the latter having a strong, spatially variable, but yet largely unquantified effect. This limits the application of a large number of staple seismological techniques (e.g., earthquake magnitude estimation, waveform tomography) that can require accurate knowledge of a signal's amplitude and frequency content. Here we present a method for accurately simulating a DAS cable and its ground coupling. The scheme is based on molecular dynamic-like particle-based numerical modelling, allowing the investigation of the effect of varying DAS-ground coupling scenarios. At first, we compute the full strain field directly, for each pair of neighbouring particles in the model. We then define a virtual DAS cable, embedded within the model and formed by a single string of interconnected particles. This allows us to control all aspects of the cable-ground coupling and their properties at an effective granular level through changing the bond strengths and bond types (e.g., non-linearity) for both the cable and the surrounding medium. Arbitrary cable geometries and heterogeneous materials can be accommodated at the desired scale of investigation. We observe that at the meter scale, realistic DAS materials, cable-ground coupling and the presence of unconsolidated materials around it dramatically affect wave propagation, each change affecting the synthetic DAS record, with differences reaching at times the same magnitude of the recorded signal. These differences show that cable coupling has to be considered both when designing a DAS deployment and analysing its data when either true or along-cable relative amplitudes are considered.



Full wavefield modelling of DAS cable and ground coupling response using Discrete Particle Schemes

Nicolas L. Celli, Nima Nooshiri, Christopher J. Bean, Gareth O'Brien

1 Abstract

Over the past several years, the use of fiber optic cables as ground motion sensors has become a central topic for seismologists, with successfu[…] Sensing (DAS) in various key fields such as seismic moni[…] characterisation.

DAS response is a combination of both instrument res[…] ground coupling, with the latter having a strong, […] unquantified effect. This limits the application of a la[…] techniques (e.g. earthquake magnitude estimation, wav[…] accurate knowledge of a signal's amplitude and frequen[…]

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We observe that a[…] presence of uncon[…] change affecting […] magnitude of the […] considered both w[…] or along-cable rela[…]

2 Introductio[…]

In the early 2000[…] cables[1], leading t[…] Distributed Acous[…] successful, pionee[…]

3.2 Modelling strain in lattices

In order to model the quantities that are natively sensed by DAS systems, we implement the computation of strain in ELM2D. Computing strain in lattices is however not straightforward[23], as strain is often expressed as the deformation of a cell rather than in terms of particle positions[24]. Since the lattice behaviour is not dictated by defined cells, this raises an issue on where to measure strain in a particle model. As we have seen, particle models are based on particle-particle interactions, so that instead of measuring the change in length of an element, we can measure the bond strain, i.e. the change in length of the bond between two particles. In a square lattice geometry like the one used by ELM2D, for a central particle i and its eight neighbours n, we can compute the bond strain as:

$$e_i^n = \frac{L_n^t - L_n^{t-1}}{L_n^{t-1}}; \qquad (1)$$

with n the neighbour index and L_n^t, L_n^{t-1} the distance between particles at the timestep t and at the previous timestep, respectively. While the bond strain in a square lattice has eight components, it can be fully represented by only four of them, as they are symmetrical around each bond: $e_i^{right} = e_{i+1}^{left}$ for two neighbouring particles at $x = i,\ i+1$. Is important to note that bond strain is measured in the direction of the bond rather than along the x,y,z axes. While this implies rotations to convert it to x,y,z strain measures, bond strain is particularly […]

[…]urs), change the […]e resulting bond […]ffect the strain […] in Figure 1) the […]in, but this also […]lified simulation

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13. Lindsey, N. J., Rademacher, H. & Ajo-Franklin, J. B. On the Broadband Instrument Response of Fiber-Optic DAS Arrays. *J. Geophys. Res. Solid Earth* **125**, 1–34 (2020).
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Figure 1: samples of various sections of the manuscript in preparation.

2. Codes

The codes for our numerical solver are hosted on the git repository at DIAS (https://git.dias.ie/seismology/elm2d-das). The repository is currently available for internal access only to control dissemination of code before the peer-review process, and we will make the code publicly available once the manuscript is accepted for publication. The repository contains all source codes for the solver, codes to plot the simulation results as well as a full online manual documenting its usage (see Figure 2, Figure 3).

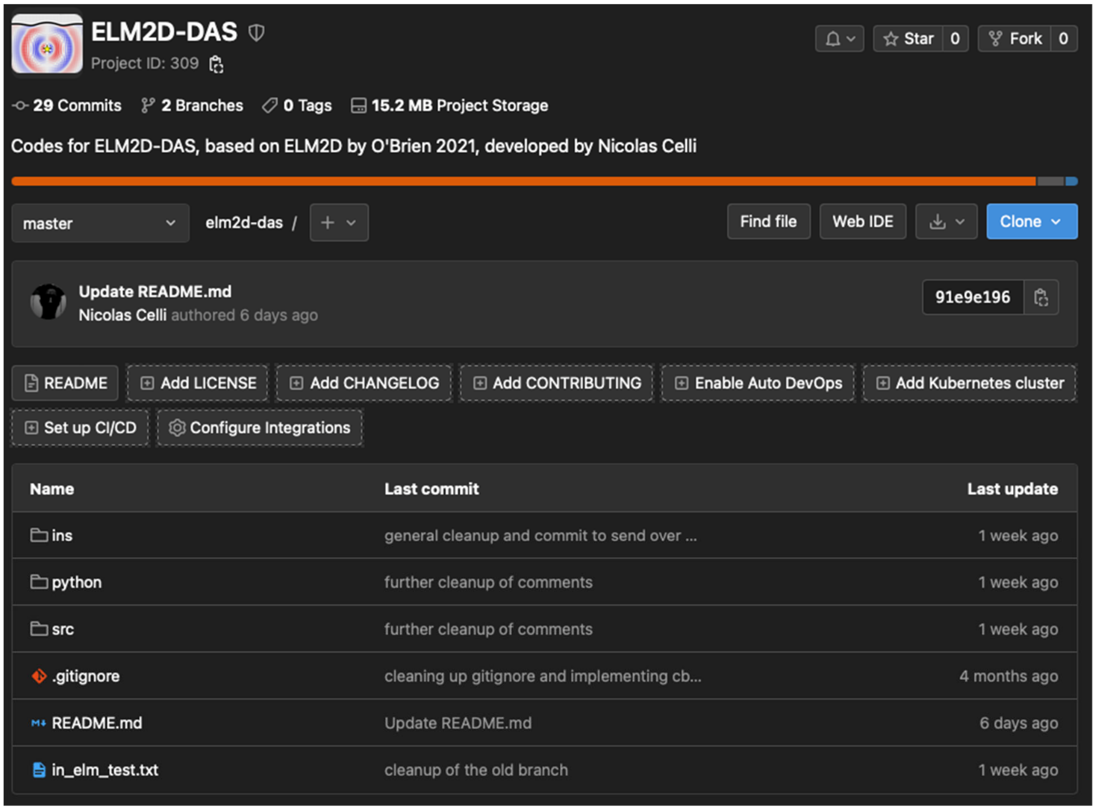

Figure 2: Main page of the git repository hosting the codes for the numerical solver.

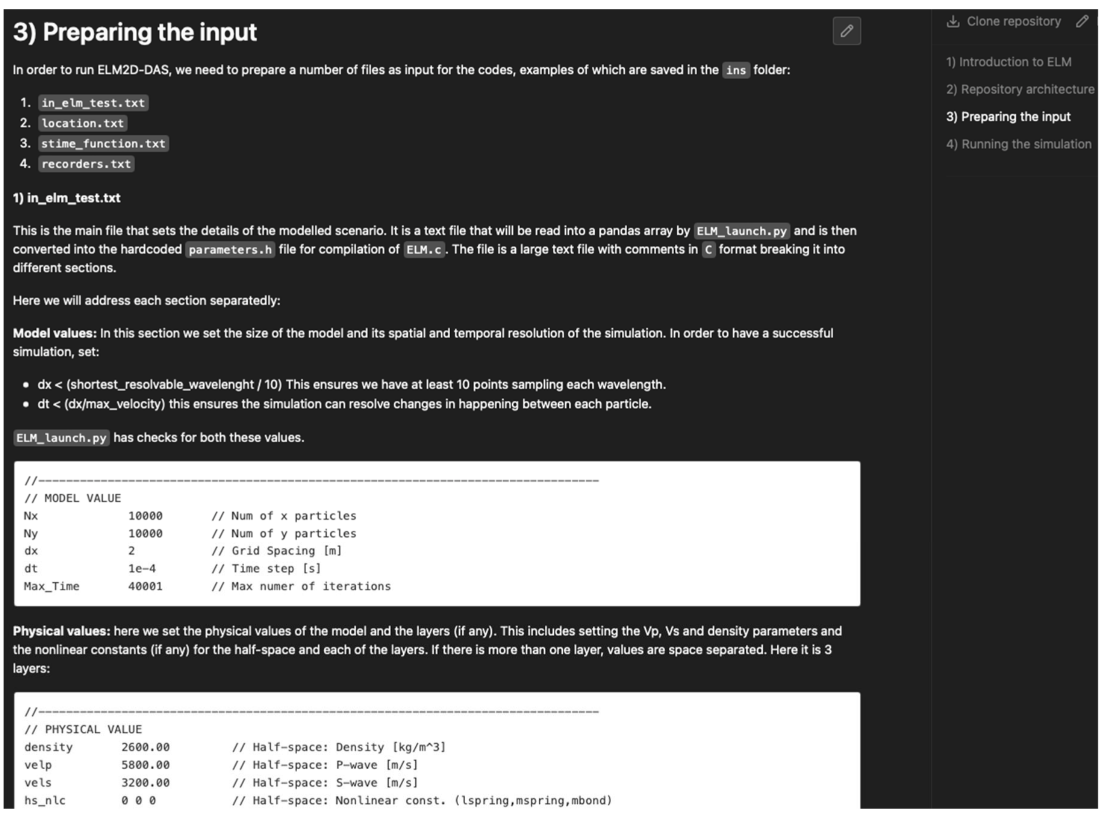

Figure 3: snapshot capturing one of the manual pages detailing the usage of the numerical solver.

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