ISSUE
02
FALL 2023

BIANNUAL NEWSLETTER

IN THIS ISSUE

Overview

It has been a busy year for the DeepWave Consortium and we are excited to share some updates. We have participated in several events that helped us to connect with peers and sponsors and showcase our work. In May 2023, we shared with our sponsors our first annual report with all the codes that can reproduce the results in the annual report. soon after, we participated in the EAGE Annual Conference and Exhibition 2023, where we presented 17 research papers that we have already shared with our sponsors December 2022. In late August 2023, we organized our first Annual Meeting in Houston, where we had the opportunity to network with our sponsors. Finally, during IMAGE 2023, our team delivered 15 talks in the technical programme, and we showcased DeepWave's main activities and team members in our booth on the Exhibition floor.

Some highlights of our exciting research projects are presented in page #3. As we continue to grow, more members have joined our ranks. Get to know them in page #4. News and more on our conference participation in page #5.

We are proud of what we achieved during this year and look forward to continuing to make strides in our field. Stay tuned for more updates!

DeepWave is an industry funded research consortium at King Abdullah University of Science and Technology (KAUST), which focuses on the application of machine (deep) learning numerical algorithms to wave-equation-based processing, imaging, and inversion.

The application of these techniques extends to objectives ranging from global Earth discovery, to natural resources exploration, to subsurface monitoring as well as non-destructive testing and medical imaging.

Goal

To be a leading center for the research and development of machine learning algorithms on waveform data with applications ranging from the exploration and discovery of the Earth to reservoir characterization and monitoring for oil and gas, geothermal, and CO2 storage purposes.

Mission

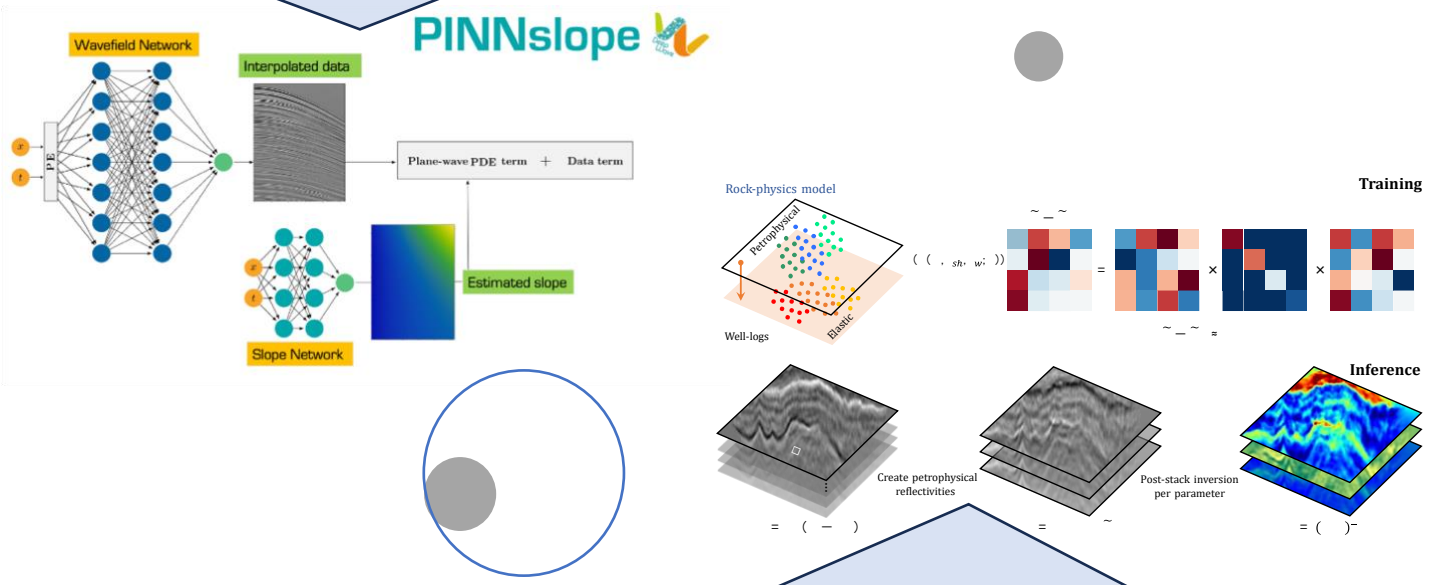
To foster an environment of effective research for the students and researchers that promotes seamless interaction with our sponsors.

Samples of DeepWave Research

PINNslope: seismic data interpolation with PINNs

Francesco Brandolin, Matteo Ravasi, and Tariq Alkhalifah

A novel PINN framework in the seismic signal processing field for simultaneous seismic data interpolation and local slope estimation. Two feed-forward neural networks are jointly trained using the local plane wave differential equation as well as the available data as two terms in the objective function. The addition of the positional encoding layer is shown to be an essential component in the PINN architecture in order to overcome previous difficulties such as high frequency fitting. Results on synthetic and field data validate the effectiveness of the proposed method in handling aliased data and data with large gaps.



Seis2Rock: A Data-Driven Approach to Direct Petrophysical Inversion of Pre-Stack Seismic Data

Miguel Corrales, Hussein Hoteit, and Matteo Ravasi

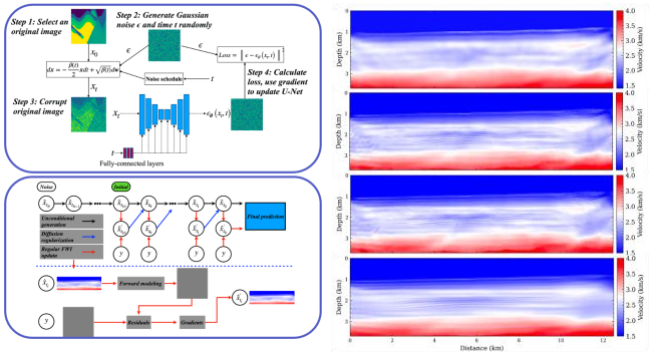
Seis2Rock, a new data-driven method, leverages optimal basis functions from well logs to link petrophysical reflectivities with pre-stack seismic data. It has two phases: training and inference. In training, singular value decomposition identifies optimal functions from synthetic AVO gathers based on elastic well-logs. During inference, seismic data is translated into band-limited petrophysical properties using these functions, followed by post-stack seismic inversion. Applied to the synthetic and field datasets, Seis2Rock effectively recovers porosity, shale content, and water saturation models. It is also used for reservoir monitoring to invert time-lapse seismic data for water saturation changes.

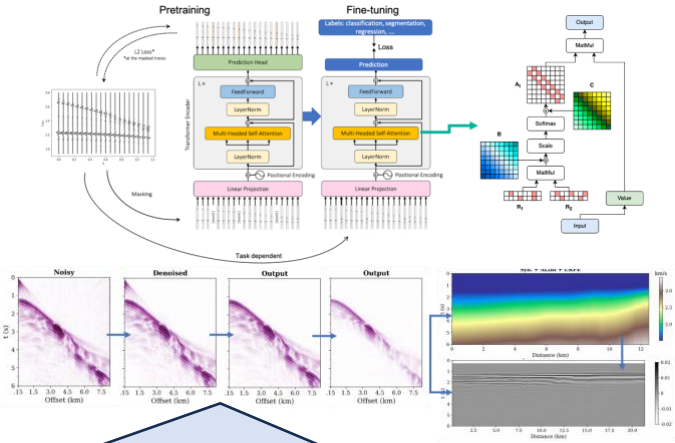
Samples of DeepWave Research

Prior regularized 2D and 3D full waveform inversion using 2D generative diffusion model

Fu Wang, Xinquan Huang, and Tariq Alkhalifah

We propose a new paradigm, combining diffusion models and FWI, makes use of a prior distribution of our expectations of the subsurface. We first pretrain the diffusion model using random velocity models guided by well information, and then implement FWI regularized by diffusion models. The beauty of the diffusion model is that we can store the main features of velocity distribution into the NN, while keeping the model size intact (no latent space), and thus, we are able to generate a velocity model belonging to the distribution via the reverse diffusion process. We have shown the effectiveness of the proposed method in 2D synthetic and field data. We further expand the proposed method in 3D FWI by using 2D diffusion model and showcase the power of the proposed method in 3D synthetic data.





An end-to-end seismic processing deep learning-based approach

Randy Harsuko and Tariq Alkhalifah

Two modifications to the vanilla StorSeismic model, a Transformer-based network with a unique pretraining and fine-tuning framework made for various seismic processing tasks, are proposed: a learnable positional encoding and low-rank attention matrices. The vanilla and new models are applied in a conventional marine seismic processing workflow, from denoising to stacking. Improvements on pretraining time, trainable parameters, and prediction results are achieved with the new model after a comprehensive test on realistic Marmousi and real field data from offshore Australia.

Omar M. Saad | *Research Scientist*

Tell us a bit about your educational background and previous research roles.

I have received a **PhD** in Electrical Engineering from the *Egypt Japan University of Science and Technology (EJUST)*. Previously I worked as a **Researcher** at the *National Research Institute of Astronomy and Geophysics (NRIAG)* in Egypt as well as a **Postdoctoral researcher** at the *School of Earth Sciences at Zhejiang University, China.*

What research projects have you completed or contributed to recently?

My previous work touches upon the fields of machine learning applications in seismology, encompassing earthquake forecasting, earthquake early warning systems, denoising, interpolation, estimation of earthquake magnitude and location. I have also being involved in projects related to Full Waveform Inversion (FWI), compression, microseismicity, and distributed acoustic sensing (DAS).

What are your first impressions being in the KAUST DeepWave team?

Being part of the KAUST DeepWave team is quite exciting and fascinating! The seamless connection between research and industry at KAUST DeepWave is remarkable. The connection between theoretical exploration and real-world impact is crucial to bridging the gap between academia and industry. It's a space where ideas don't just stay theoretical but have the potential to shape and revolutionize the industrial landscape. I'm excited to start utilizing the power of deep learning, explore, and innovate with the DeepWave team in different applications.

Xiao Ma | *PhD Student*

Xiao received his **Bachelor** from Chengdu University of Technology (China) and his **MSc** from China University of Petroleum (Beijing).

His research interests are seismic data denoising, fault detection, microseismicity, and deep learning.

New Members

Our team is growing. Learn more about our new additions here.

News

• First Annual Report

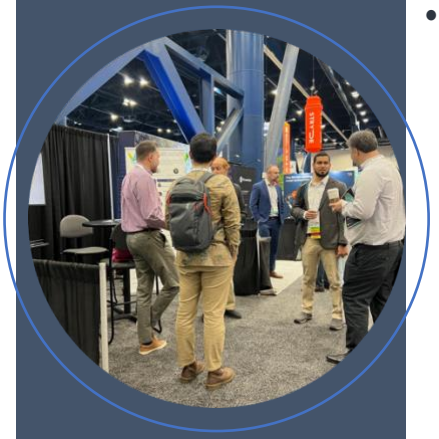
The Consortium 1st Annual Report came out in early June. It consisted of 17 Chapters providing insights of our research over the past year. The report is available for download for our sponsors only from the Restricted Area on our website.

• DeepWave @ EAGE 2023

The members of DeepWave were in Vienna, Austria and presented a total of 17 oral presentations. For a detailed list of the topics presented, visit our consortium website.

• 1st DeepWave Annual Meeting

Our research members from KAUST and colleagues from our sponsor companies came together for the first annual meeting of the consortium in the One Allen Center (Houston, TX). Our latest research was presented in 5 sessions followed by open discussions where sponsors shared ideas and suggestions aimed at shaping the consortium's future directions.



• DeepWave @ IMAGE 2023

The consortium's first booth in the Exhibition of the International Meeting of Applied Geoscience & Energy (IMAGE) 2023 attracted visitors from both academia and industry. The booth gave us the chance to promote the consortium's research and explore collaborations. Furthermore, during the Technical Conference Sessions, our members gave 11 oral presentations and presented 4 posters.

- **Tariq Alkhalifah receives the Society of Exploration Geophysicists' Kauffman Gold Medal**

Alkhalifah received the award at the third annual International Meeting for Applied Geoscience & Energy 2023 (IMAGE '23). The Kauffman Gold Medal is awarded to "a person who has made an outstanding contribution to the advancement of the science of geophysical exploration as manifested during the previous five years. The contribution may be of a technical or a professional nature."

- **Mid-year Meeting 2024**

DeepWave is embarking on new and exciting research. Our next get-together with our sponsors is scheduled for the first quarter of 2024, where we will share more results at the consortium's Mid-year Meeting. Stay tuned for more details on this event!

- **DeepWave on Github**

Our Github organization has been growing thanks to the contribution of our prolific team. The organization is currently hosting 18 stable repos and 8 repos under development. All are created to provide seamless sharing of codes between the DeepWave researchers and the Consortium sponsors. Sponsors are encouraged to provide their GitHub username to be included in the organization.

Scope of research

The Consortium aims to deliver the most effective solutions to waveform processing, imaging, and inversion challenges across multiple scales.

We thank our **Industry Sponsors** for their support

4700 King Abdullah University of Science and Technology
Thuwal 23955-6900
Kingdom of Saudi Arabia

deepwave@kaust.edu.sa

deepwave.kaust.edu.sa