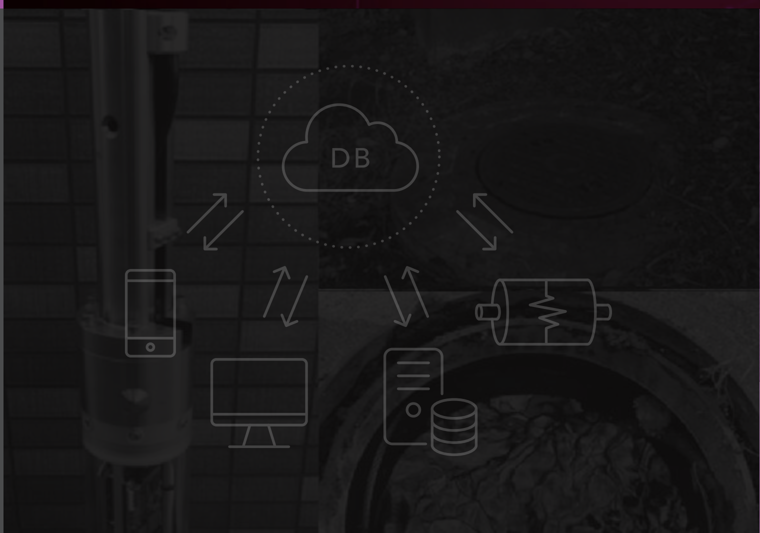
Seismology Toward Research Innovation with
Data of Earthquake (STAR-E Project) promoted by MEXT

SYNTHA-Seis

NEWSLETTER

Vol. 03
June 2025

Synergy effect Through Human and Artificial Intelligence Towards New Era in Seismology



$$\rho \frac{\partial^2 \mathbf{u}}{\partial t^2} = (\lambda + 2\mu)\nabla(\nabla \cdot \mathbf{u}) - \mu \nabla \times (\nabla \times \mathbf{u}) + \mathbf{f}$$

$$L = -\sum_c \sum_i q_{c,i} \log p_{c,i}$$

$$(f * g)(t) = \int_{-\infty}^{\infty} f(\tau) g(t-\tau)\, d\tau$$

$$S = \begin{pmatrix} \Sigma_1 & \cdots & 0 \\ \cdots & \Sigma_v & \cdots \\ 0 & \cdots & \Sigma_V \end{pmatrix}$$

$$f(M) = \sum_{k=1}^{K} w_k \times \mathrm{Wishart}_{\nu_k}(M|S_k)$$

$$\mathrm{Attention}(Q, K, V) = \mathrm{softmax}\left(\frac{QK^\top}{\sqrt{d_k}}\right) V$$

Top Leaders Dialogue

A Synergistic Spiral is Upcoming in the AI and Seismology Fusion.

SYNTHA-Seis leads the interaction in the field of "Information Science x Seismology" from an interdisciplinary and international perspective.

SYNTHA-Seis, which set sail in 2021, is finally about to reach its port of arrival. From 2024, we welcome Prof. Yoshikazu Terada, who has many achievements in information science, statistics, and their applied research, as the new leader of the University of Osaka team. He has already made his presence in seismology, which is very encouraging as a principal investigator. As reported in this issue, we have promoted joint research between seismology and information science researchers and started joint research between the California Institute of Technology (Caltech) and ERI. Under our international exchange agreement, we invited three researchers from Caltech and dispatched a young project researcher from ERI for three months. We are steadily building a human network of "information science x seismology" researchers in Japan and abroad. In 2025, the final year of the project, we will provide data analysis techniques developed through dialogue and collaboration between artificial intelligence and natural intelligence to seismology. We appreciate continuous support for SYNTHA-Seis, which aims to develop and establish the field of "Information Science × Seismology".

Principal Investigator: Hiromichi Nagao
Associate Professor, Earthquake Research Institute, The University of Tokyo

Earned Dr. of Science at Graduate School of Science, Kyoto University in 2002. After working at the Japan Atomic Energy Agency, the Japan Agency for Marine-Earth Science and Technology, and the Institute of Statistical Mathematics, he has been working at the current position since 2013. He specializes in the interdesciplinary research between applied mathematics, statistics and solid earth science.

Since my doctoral studies, I have specialized in the statistical theory of unsupervised learning with a focus on clustering methods, and have been involved in research on fMRI data analysis and functional data analysis. Dr. Nagao's invitation brought me into contact with earthquake data for the first time, and I believe that unlabeled data science is an important issue in seismology, where the mechanisms are complex, and is a very challenging topic for statistical seismology. Specifically, I would like to work hard to contribute to seismology from the viewpoint of information science, for example, in the prediction of shaking and immediate damage estimation at locations where there are no observation points.

Co-Principal Investigator: Yoshikazu Terada
Associate Professor, Graduate School of Engineering Science, The University of Osaka

After working at the National Institute of Information and Communications Technology (NICT) Brain Information and Communication Fusion Research Center, he joined the Graduate School of Engineering Science, the University of Osaka in 2016 and has been working at the current position since 2020. His areas of expertise are statistical science and machine learning with a focus on unsupervised learning.

Interview Hiromichi Nagao × Yoshikazu Terada

Top Leaders Dialogue

A Synergistic Spiral is Upcoming in the AI and Seismology Fusion.

Principal Investigator: Hiromichi Nagao
Associate Professor,
Earthquake Research Institute, The University of Tokyo

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Co-Principal Investigator: Yoshikazu Terada
Associate Professor,
Graduate School of Engineering Science, The University of Osaka

Nagao: Dr. Terada has been involved in this project as a research partner since its inception. What are your frank impressions about taking over from Dr. Morikawa as the representative of your group?

Terada: I had the opportunity to enter seismology when Dr. Morikawa joined as the representative of our group. I have studied the theoretical part of statistics, but how to apply it? The problem of statistics itself comes from the application, so I am happy to be a part of this important aspect of the project, to know the real issues and solve them from there, as a developer of data science methods in statistics.

Nagao: What was your image of seismology before you got involved?

Terada: I had no contact with seismology, so I didn't really understand it, but I had the impression that the mechanism was difficult. I thought it was a challenging discipline.

Nagao: I often hear from statisticians and other people in the mathematical and information fields that they came into earthquake research easily, but when they tried it, it was more difficult than they expected. Do you think you can do something in seismology?

MESSAGE Tomoyuki Higuchi

STAR-E Project Manager:
Tomoyuki Higuchi
Professor, Faculty of Science and Engineering, Chuo University

This project focuses not only on the automation of work through the use of AI to cope with the increasing scale and precision of seismic observation data, but also on the AI-ization of the keen eyes of data analysis experts. We have high expectations for steady progress in the development of fundamental and practical methods that contribute to the advancement of work processes in the current industry through both automation and intelligence. Furthermore, we hope that the results of this project will lead to the creation of systems that can reduce damage caused not only by earthquakes, but also by various other natural disasters.

Terada: It depends. In particular, physical mechanisms are an unexplored area of statistics, and since it is outside my field of expertise and I have no knowledge of it, I don't know how to tackle it. However, I felt that there was room for me to contribute to the problem of small data and the computational cost aspect of simple smoothing, even though I hadn't imagined it at first.

Nagao: If you could be involved further, what would you be able to do?

Terada: I expect that there will be a phase where unsupervised learning will play an important role. I would be happy to create tools to discover meaningful signals from unlabeled data.

Nagao: Dr. Hirata also said that unsupervised learning is quite tough. It would be quite powerful if such tools could be created.

Terada: Besides, we would like to extend the aftershock time distribution estimation to solve the problem of computational cost and to ensure the stability and validity of the estimation. The fast smoothing method used for wave field imaging is a versatile and effective for spatio-temporal data, especially for low-frequency motions, not only in seismology.

Nagao: Currently, it is still impossible to predict earthquakes, but if we can analyze seismograph data and estimate tremors at high speed, we can provide information to society in the form of seismic wavefield prediction. Do you think this technology is feasible?

Terada: I would like to reach the point where my methods are implemented in society, but I cannot do it alone. Cooperation with related researchers and engineers in the field is essential.

Nagao: I have been working hard to build a human network between seismologists and statisticians for a long time, and I feel the collaboration is going well this time. We need to add more people from the actual business world for social implementation. By having mathematical statisticians like Dr. Terada speak up and share his views, I would like to build an all-round system from basic research to social implementation. We don't want to end with just basic research.

Terada: As a researcher, I am happy to be able to feel that I am contributing to society. I like that myself.

Nagao: By the way, this year's Nobel Prize was awarded for research on a theme related to artificial intelligence (AI). That was shocking, wasn't it?

Terada: I was really surprised. It was a physics prize and a chemistry prize. It is a kind of turning point. AI, led by large-scale language models, has entered our daily lives. I feel that this is about five years earlier than expected. I think we may have to make assumptions about how to make good use of AI hereafter.

Nagao: Basic AI research has been conducted for a long time, but it is difficult to evaluate it by itself. The research is evaluated only when it leads from basic to applied research and then to social implementation, or to our social life. In addition, I have the impression that the distance from basic research to social implementation is still quite far off in Japan. I feel that it would be better to further strengthen the mechanism that enables immediate linkage between basic research and applied research.

Terada: New technologies today are always linked to applications. The generative model is the idea of a new data model, and people who are developing AI also have to think about what outputs are. Because the basic research now may be important decades later.

Nagao: Here too, we need to build a bridge to social implementation. Are there any other issues?

Terada: AI is booming, but the classic problem is that there is a lack of seismic data.

Nagao: I agree. This is where AI can help. I would like to see a cycle in which AI analyzes what kind of new observation data is needed, AI predicts unobtained observation data, and then AI analyzes it again. Another major challenge with AI is that it can tell you the answer, but not the thought process. While some researchers are developing AI to detect earthquake-related events from seismic waveforms, other seismologists still rely on physical interpretation. How can AI respond to this?

Terada: AI can show us where it focused its attention partially, but it has yet to explain the mechanism behind. XAI is gaining momentum in the AI field, but many methods only use local linear models to explain and are not sufficient to interpret the behavior of the entire system. Especially since earthquakes are physical movements, I think we need to work with people who are doing numerical analysis and model characterization.

Nagao: In the future, we would like to improve our methods so that they can be applied not only to seismology but also to other fields such as volcanology. First, we will incorporate unsupervised learning, which is already available as a technique. Then, we would like to work together to come up with innovations that can answer the "why" of seismologists.

Terada: Let's make it active together!

01 Wishart Mixture-based Multiple Clustering for Selecting Seismic Stations for Low-frequency Earthquake Detection

Tomoki Tokuda
Project Assistant Professor, ERI, UTokyo
After completing a PhD in Psychology at the University of Leuven in 2012, I worked at the Okinawa Institute of Science and Technology Graduate University and Advanced Telecommunications Research Institute International (ATR), where I developed methods for analyzing neuroscience data.

In recent years, earthquakes with lower frequency than normal seismic waves (hereafter referred to as "low-frequency earthquakes") have attracted much attention in seismology. Low-frequency earthquakes occur more slowly and with a longer duration than normal earthquakes. It is thought that low-frequency earthquakes are related to the slow slip of faults that cause earthquakes. In particular, low-frequency earthquakes occurring on plate boundaries are considered to be related to the accumulation of strain that eventually triggers large earthquakes. However, the amplitude of the observed seismic waveforms is small, and hence it is not easy to detect them at a single seismic station. To effectively detect low-frequency earthquakes, waveform data from multiple stations need to be analyzed simultaneously. Ideally, the necessary and sufficient number of stations should be selected for each low-frequency earthquake, but it is difficult to identify such stations in advance, and no method has been established for this purpose. In this study, we tackled the problem of selecting such seismic stations from a new perspective of low-frequency earthquake classification.

We focused on the fact that the similarity (cross-correlation) of seismic waveforms between specific seismic stations increases when a low-frequency earthquake occurs. For low-frequency earthquake detection, we attempted to select such seismic stations using a machine learning method known as "multiple clustering" (Ref. 1). The main feature of the multiple clustering method is that it can simultaneously estimate a set of seismic stations that show similarity in seismic waveforms and an event classification model for low-frequency seismic events. Figure 1 shows a schematic diagram of this method. In this figure, red triangles represent seismic stations, whereas blue lines connect stations with high waveform similarity between them. For example, selecting seismic stations A, B, D, and E suggests that seismic events EQ1, EQ2, EQ3, and EQ4 can be detected. On the other hand, selecting seismic stations C and F suggests that seismic events EQ5 and EQ6 can be detected. For real data, the relationship between seismic stations and low-frequency seismic events may not be always as clear as it is in the schematic, but, the multiple clustering method can optimally estimate the best combination of station selection and event classification from the data. This method was developed for cluster analysis in the field of neuroscience and applied to the classification of mental disorders using MRI brain imaging data (Ref. 2). Despite that neuroscience and seismology are completely different scientific fields, the mathematical expressions abstracting the object of analysis have the same problem setting; hence, the same statistical methods can be applied for these different fields.

In this analysis, we used 10-minute waveform data (spectrograms) for 173 low-frequency earthquakes observed at 88 stations in the Tohoku region in 2015. Waveform similarity between stations was first evaluated, followed by the application of the multiple clustering method. As a result, it was found that those stations could be divided (selected) into 11 station groups (Figure 2). Although there were some station groups that did not detect low-frequency earthquakes well (e.g., station group 4 in Figure 2), the locations of the station groups and detected low-frequency earthquakes well corresponded (e.g., station group 1), suggesting that the station selection was appropriately made. More interestingly, the event classification model identified multiple low-frequency earthquake clusters. These clusters may be related to the underlying mechanism of low-frequency earthquake occurrence. In the future, we would like to further refine this method and detect low-frequency earthquakes that have not been previously recorded in seismic catalogs, as well as to verify the differences in the underlying mechanism behind the clusters of low-frequency earthquakes.

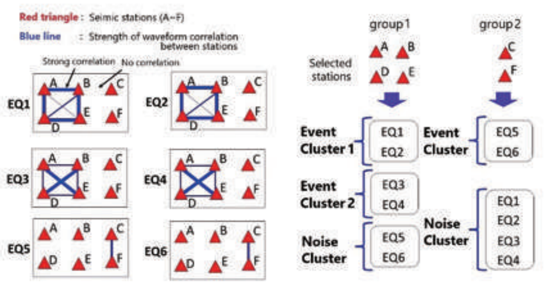


Figure 1: Schematic diagram of the multiple clustering method. For six events (EQ1-6), the multiple clustering method identifies station groups and event categories using waveform correlations between stations A-F. For the station group of A, B, D, and E, the events EQ1, EQ2, EQ3, and EQ4 are classified as seismic events because of non-zero waveform correlation, whereas EQ5 and EQ6 are classified as noise (cluster) because they have no waveform correlation. Further, based on the correlation patterns, the seismic events are further subdivided into event cluster 1 (EQ1, EQ2) and event cluster 2 (EQ3, EQ4). In the same manner, for the station group of C and F, the events EQ5 and EQ6 are classified as event cluster, whereas EQ1, EQ2, EQ3 and EQ4 are classified as noise cluster.

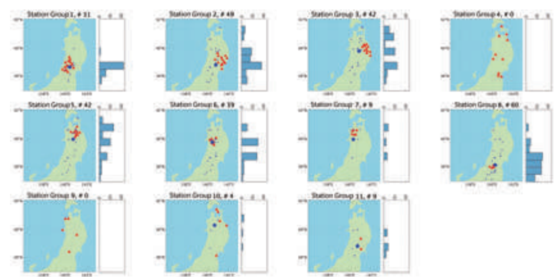


Figure 2: Results of application of the multiple clustering method. Selected seismic stations are denoted as red triangles, whereas the epicenter locations of the detected low-frequency earthquakes and the median epicenters as blue dots and a blue circle, respectively. The histogram displayed in each panel shows the latitudinal distribution of low-frequency earthquakes (latitude corresponds to the latitudinal coordinate on the left of the panel). Further, the number of low-frequency earthquakes detected is displayed in the panel title.

References:
[1] Tokuda, T., & Nagao, H. 2023. Wishart Mixture-based Multiple Clustering for Selecting Seismic Stations for Low-frequency Earthquake Detection, Japanese Journal of Statistics and Data Science: 52 (2), doi.org/10.5023/jappstat.52.99
[2] Tokuda, T., Yamashita, O. & Yoshimoto, J. 2021. Multiple clustering for identifying subject clusters and brain sub-networks using functional connectivity matrices without vectorization, Neural Networks: 142, doi.org/10.1016/j.neunet.2021.05.016

02 Creating a Template Catalogue of Microtremors Using RMS and Hierarchical Clustering

Gerardo Mendo Pérez
Project Researcher, ERI, UTokyo
Specializes in seismology, volcanic seismology, and volcanic acoustics. Researches the development of new methods for detecting seismic waves.

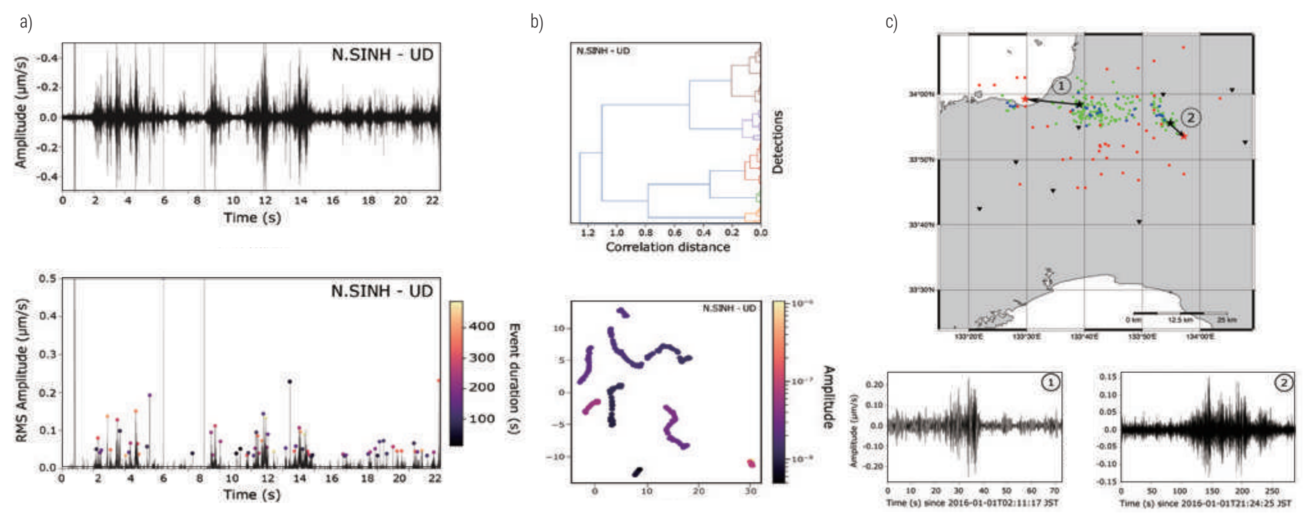
Slow earthquakes are a type of fault-slip phenomenon characterized by a longer duration than normal earthquakes. Slow earthquakes are mainly observed in subduction zones and are thought to be related to the occurrence of large earthquakes. 2002 was the first year that slow earthquakes were discovered, and since then research has been conducted to unravel the mysteries behind the process of this phenomenon. Slow earthquakes (LFEs and microtremors) have relatively small amplitudes similar to background noise, making their detection a challenge. Various methods have been developed to detect and locate LFEs and crustal microtremors. The most commonly used are the envelope correlation method (Obara, 2002), the modified envelope correlation method (Mizuno and Ide, 2019), and the matched filter method (template matching method) (Shelly et al., 2006). Although template matching methods are very useful, they require a catalog of template waveforms and can only detect waveforms that are similar to those in the catalog. To address this problem, this study proposes a method based on unsupervised clustering as a complement to the template matching method. The proposed method, called You Only Search Once (YOSO), automatically extracts template waveforms that are input to an algorithm that performs template matching.

YOSO consists of the following three steps

1) Detect microtremor events by estimating the root mean square (RMS) envelope of filtered seismic waves in the frequency range of 1 to 10 Hz.
2) Estimating the duration of each event by evaluating the RMS amplitude decay
3) Apply agglomerative hierarchical clustering using amplitude ratio, duration ratio, and correlation coefficient to classify detected events.

One of the features of YOSO is its ability to accurately estimate the duration of all template waveforms.After confirming the performance of duration estimation using artificial waveforms generated by the Brownian motion model (Ide, 2008), YOSO was applied to seismic waveform records obtained at Hi-net central Shikoku stations (see Figure a below). 160+ microtremor events were detected in the January 1, 2016 record, and clustering based on amplitude and duration yielded approximately 7 to 9 clusters (see Figure b below).Clustering quality was evaluated using three indices: the Silhouette coefficient, the Davies-Boulin index, and the Calinski-Harabasz index. The cluster structure was clear when the amplitude ratio and duration ratio were used, but not when the correlation coefficient was used. In addition, it was found that local earthquakes, regional earthquakes, and microtremors could be clearly distinguished when amplitude ratios were used, while local earthquakes and microtremors could not be distinguished when duration ratios were used. Furthermore, we applied the amplitude information to the ASL method (Battaglia and Aki, 2003) to obtain the epicentral distribution of microtremors detected in YOSO and compared it to the epicenters in the Mizuno and Ide (2019) microtremor catalog and the NIED source catalog on the same day (see Figure c below). Although the epicenter could not be identified, the detected waveforms were found to be part of a series of microtremors. The normalized energies of these events were in the 10^{-9}~10^{-11} range, suggesting that they corresponded to microtremors.

Several issues regarding YOSO were also identified. First, the results of hierarchical clustering are very sensitive to the clustering parameters, and the elements in the clusters may vary from station to station. Second, it is not easy to identify the source of microtremors. In the future, we hope to develop techniques to identify the source of microtremors and further improve the method; we expect that YOSO will improve upon the traditional template matching method and become a promising method to accurately detect microtremors even without a template waveform.



a) Vertical motion component waveforms at the Hi-Net Shikoku central station and detection results by RMS envelope estimation. Circles in the figure below indicate detected events, and circle's color indicate the estimated duration of each event.
b) Hierarchical clustering dendrogram of detected events evaluated by similarity and UMAP by amplitude ratio between detected events.
c) Epicentral distribution of microtremors detected at YOSO (red dots), compared to the event catalogs of Mizuno and Ide (2019) (green dots) and NIED (blue dots). In the figure below, two examples of microtremor waveforms of clusters detected by YOSO. (Equivalent to ① and ② above. Arrow lines indicate the same event.) These can be newly added to the microtremor templates catalog.

03 Development of Seismic Wave Run-Time Reading Model Using Vision Transformer

Shinya Katoh
Project Researcher, ERI, UTokyo
D. from Kyoto University in 2023. Specializes in automatic seismic wave processing and estimation of crustal structure using deep learning.

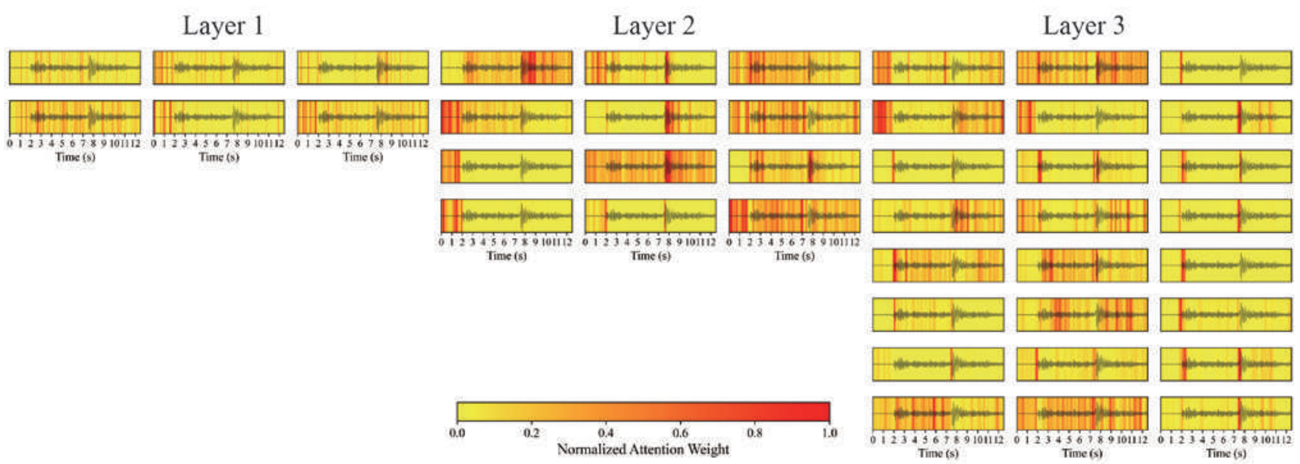
Analysis of seismic waveform data is fundamental research in seismology. In particular, "phase picking," which identifies the arrival time of P- and S-waves from seismic waveforms, is essential for creating earthquake catalog and monitoring of seismic activity. However, the amount of observed waveform data is enormous, and manual analysis is highly time-consuming and labor-intensive. To address this challenge, automated approaches using deep learning have gained significant attention in recent years. In this study, we developed a new phase-picking model, SegPhase, designed to efficiently and accurately process data from high-density seismic networks in Japan.

SegPhase applies a state-of-the-art deep learning technology called Vision Transformer (ViT) to seismic waveform analysis. ViT was originally developed for image recognition and can capture global features. A core component of ViT is the Multi-Head Self-Attention (MHSA) mechanism, which enables the model to selectively focus on important regions of the input. The MHSA can extract the seismic waveforms from the data and focus attention on the features that are most important for the seismic data. Multiple "heads" extract different features in parallel, providing comprehensive learning of diverse patterns in the waveform data. Shallow layers distribute attention over the entire waveform, while deeper layers focus on seismologically important features such as P-wave and S-wave arrival points. This structure allows SegPhase to efficiently learn both local and global features, resulting in highly accurate phase picking. This architecture results in highly accurate phase picking and provides interpretable results through attention map visualizations, highlighting which segments of the waveform the model focused on during prediction.

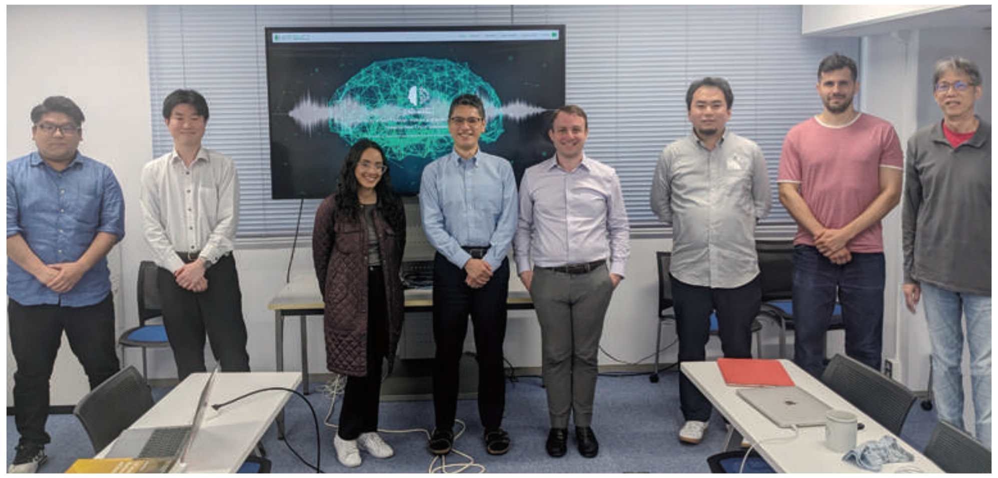
The performance of SegPhase was evaluated by comparing it to conventional models. Compared to CNN-based models, SegPhase produced results that were more consistent with manual picks by human experts. In particular, attention mechanism of ViT was highly adaptive and showed reliable results in noisy environments and for data with complex waveform structures. Furthermore, SegPhase maintained stable performance across varying output probabilities (representing model confidence), epicentral distances, and signal-to-noise ratios (SNR). The use of SegPhase for automatic earthquake cataloging also led to the detection of more small events. In particular, lowering the threshold for output probability allowed the model to make better use of high-confidence predictions, increasing the number of detectable earthquakes and enhancing the potential for detailed tomographic studies and crustal structure analysis.

However, SegPhase has some issues. In particular, the model's accuracy tends to decrease when multiple seismic waves overlap in the same input. Addressing this issue will require expanding the model's capacity and training it on more diverse datasets.

The introduction of SegPhase enables automatic analysis of large seismic data. This technology will contribute to data processing of high-density observation networks, detection of small earthquakes, and more detailed source determination. In the future, we aim to develop a more comprehensive seismic waveform analysis model by integrating additional elements such as P-wave first-motion polarity classification. This research represents an important step toward providing a new technological foundation for earthquake disaster preparedness and mitigation.



Attention maps are shown for all heads for the seismic input, indicated by the black line, where Layer indicates the number of layers, with Layer1 being the shallowest and Layer3 the deepest. The attention map shows the attention normalized to the maximum value. Normalized attention values close to 1 (red) indicate that the model is paying stronger attention.



Sep.– Dec. 2024

My stay in America

Shinya Katoh
Project Researcher, ERI, UTokyo

From September to mid-December 2024, I stayed at the Seismo Lab at the California Institute of Technology (Caltech) to collaborate with Dr. Zachary E. Ross. The goal of this research is to develop a new method for determining epicenter location using deep learning for events such as deep low-frequency earthquakes, where the arrival time of seismic waves is difficult to determine. Specifically, we explored a method that uses a deep learning model to reproduce the wave propagation of seismic waves and estimate the epicenter location based on this model.

Dr. Ross's research group is one of the earliest researchers to use deep learning models in the field of seismology, and during my stay, Dr. Ross provided me with detailed explanations and practical advice on the latest deep learning technology, which was of great help. This collaboration, which is still ongoing, has provided us with important insights into further potential applications of deep learning in seismology. In addition to the research findings, I also gained a lot of inspiration during my stay at Caltech in terms of how to approach my research and how to carry out academic discussions. I had a valuable opportunity to broaden my own research horizons.

In addition to my stay at Caltech, I also participated in the Earthquake Research Institute's 100th Anniversary Workshop in New York, where I presented my research to researchers from the Lamont-Doherty Earth Observatory (LDEO) and held discussions. I also received valuable feedback from LDEO researchers on my research, and gained new perspectives and ideas. The experience of this stay not only gave me a new direction in my research activities, but it also provided me with an opportunity to further increase my motivation and passion for research. I would like to continue this collaboration and use this knowledge and experience to help solve problems in the field of seismology.

ACTIVITY REPORT

Prof. Zachary E. Ross's group of Caltech visited ERI [2024.4.3-22]

JpGU2024(Japan Geoscience Union's Annual Meeting) Sessions [2024.5.26-27]

JSAI2024(Japanese Society for Artificial Intelligence's Annual Meeting) Session [2024.5.30]

Summer School in ERI [2024.8.7-9]

JFSSA2024(Japanese Federation of Statistical Science Associations's Annual Meeting) Session [2024.9.4]

SSJ2024(Seismological Society of Japan's Annual Meeting) Session [2024.10.22]

JSAS(Japanese Society of Applied Statistics) 2024 Symposium [2024.11.17]

AGU24(American Geophysical Union's Annual Meeting) [2024.12.9-13]

Spring School in ERI [2025.3.19-28]

AWARDS

Prof. Hiromichi Nagao and Dr. Tomoki Tokuda received "Best Paper Award 2024" from Japanese Society of Applied Statistics. [2024.5.9]

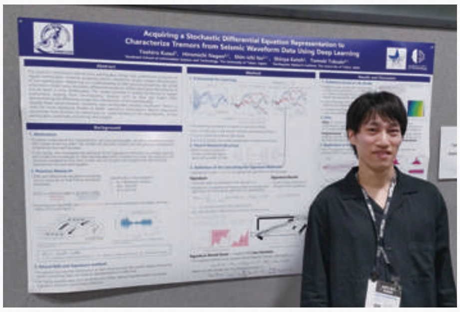
Dr. Shinya Katoh received "The Grand Prize in Seismology" at GeoSciAI2024. [2024.5.26]

Toshiro Kusui received "Good Presentation Award for Students 2025" from Japanese Society of Applied Statistics. [2025.5.17]

AGU24 Report

Reported by Toshiro Kusui
Doctoral student 1st grade, UTokyo

In December 2024, I participated in the AGU Annual Meeting held in Washington, D.C., USA. It was my first experience. In addition to having a chance of listening to valuable lectures by researchers working at the forefront of earth science, I myself gave a poster presentation on a method for mathematically modeling the envelope of low-frequency microtremors using deep learning, and had lively discussions with many participants. Although I was not used to communicating in English at first, my active participation in the poster presentation gave me the opportunity to directly exchange opinions with many researchers. The opinions and questions I received during these discussions were very helpful for my future research. In particular, it was stimulating and very meaningful to interact with researchers who are applying statistical methods and deep learning to earthquake research. I encountered interesting earthquake research that utilizes Bayesian methods and physical deep learning, and I was able to hear detailed stories about their research. I would definitely like to stay connected with these researchers in the future. AGU is the world's largest conference for all earth sciences, and there were numerous presentations on a wide range of topics besides seismology. I was overwhelmed by the diversity of the presentations, and at the same time, I was inspired by many presentations from other fields. I listened to oral presentations from other earth science fields. Since I have a strong interest in mathematical methods in general, being exposed to new methods in fields other than seismology gave me a perspective on how these methods can be used in earthquake research. I felt that this kind of intersection with research in different fields was also a significant part of my experience at the international conference.



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