

## Research Result Report

### ICRR Inter-University Research Program 2023

Research Subject:

Applications of machine learning technique on gravitational wave detection

Principal Investigator:

Yi Yang

Participating Researchers:

Yi Yang

Hong-Yin Chen

Summary of Research Result :

This report presents our work on the development and application of DeepClean, an advanced machine learning model, in the context of KAGRA data analysis. DeepClean, employing convolutional neural networks, significantly reduces noise in raw strain data, a critical aspect of gravitational wave detection.

**1. Introduction and Objectives:** Our research is centered around the development of DeepClean and its application in analyzing KAGRA data. The primary objective is to enhance the signal-to-noise ratio in gravitational wave detection by effectively reducing background noise.

**2. Methodology:** DeepClean utilizes data from multiple monitors, termed 'witness channels', strategically placed throughout the KAGRA detector. These channels assist in capturing background noise, which DeepClean processes through complex non-linear transformations. By employing a meticulously designed loss function, DeepClean predicts and subtracts noise, resulting in a substantial improvement in the signal-to-noise ratio.

**3. Experimental Results:** We conducted extensive tests on DeepClean's effectiveness in reducing 60 Hz AC power noise from KAGRA O3GK and O4a strain data. Our findings demonstrate a dramatic reduction in the 60Hz noise peak in the processed data. Additionally, we identified various other noise sources, such as 'violin modes'—thermal oscillations in the strings suspending the mirrors—during the O4 run. Addressing these noises posed a challenge due to the absence of corresponding witness channels. However, our preliminary experiments with a 'single sine wave' model have yielded promising approaches to mitigate these issues.

<p><b>4. Infrastructure Development:</b> On September 28th, we successfully installed a GPU server in KAGRA, detailed in the KAGRA logbook. Equipped with dual A30 GPUs, this server plays a pivotal role in real-time, low-latency DeepClean processing, essential for multi-messenger astronomy. During the testing phase, this server operates within the iCRR network for security and accessibility. Plans are underway to transition to the DMG network in preparation for online deployment, ideally before the O5 run.</p> <p><b>5. Significance and Future Applications:</b> The GPU server is instrumental in online noise reduction for low-latency gravitational wave detection. Initially focusing on 60Hz AC power noise, we aim to extend its capabilities to address other noise sources, like violin modes. The server will also facilitate various machine learning projects, including glitch classification and rapid sky localization. Ultimately, DeepClean represents a significant advancement in reducing background noise in gravitational wave strain data, enhancing parameter estimation, and supporting low-latency detection.</p> <p><b>6. Conclusion:</b> The integration of DeepClean into KAGRA's data analysis framework marks a substantial leap forward in gravitational wave research. With its dual offline and online processing capabilities, DeepClean, supported by the newly installed GPU server, is poised to revolutionize both gravitational wave detection and broader machine learning research within this domain.</p>
---

No.
-----