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Transformers + Normalizing Flows for parameter estimation of overlapping gravitational waves in next generation detectors

In the next decade, the third generation of ground-based gravitational wave detectors, such as the european Einstein Telescope, is expected to revolutionize our understanding of compact binary mergers. With a 10 factor improvement in sensitivity and an extended range towards lower frequencies, Einstein Telescope will enable the detection of longer-duration signals from binary black hole and binary neutron star coalescences, with expected rates up to ~10^5 events per year. However, the inevitable presence of overlapping signals poses a severe challenge to parameter estimation analysis pipelines.
In this talk, I will describe a foundation model for parameter estimation, leveraging the synergy of two state-of-the-art machine learning architectures: Transformers and Normalizing Flows. The Transformer component efficiently encodes the complex temporal structures of overlapping signals, capturing long-range dependencies, while Normalizing Flows provide a flexible, efficient representation of the high-dimensional posterior distributions of source parameters.
I will show how this hybrid approach enables rapid and accurate inference, even for low-SNR and highly correlated events. By significantly reducing the computational cost while maintaining accuracy, this framework represents a crucial step toward integrating machine learning-driven inference into real-data analysis pipelines for third-generation detectors. I further present performance benchmarks on simulated data, showcasing the potential for real-time parameter estimation, and discuss future developments.

AI keywords

Transformers, Normalizing Flows, Simulation based inference

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