Citizen-Driven Computational Timing Anomalies as Auxiliary Probes of Gravitational Waves

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***Abstract*—Gravitational waves (GWs) have been observed by LIGO and Virgo in the frequency range 10 Hz–10 kHz, confirming one of the key predictions of general relativity. While these interferometers are state-of-the-art instruments, auxiliary methods that complement them in different frequency ranges or through alternative detection strategies could open new avenues in GW astronomy. This paper proposes a novel approach: leveraging the timing stability of modern computing systems (CPUs, GPUs, and memory caches) as indirect probes of GW-induced perturbations. Our method exploits deterministic artificial neural network (ANN) workloads and ultra-stable computational benchmarks to detect deviations in instruction throughput during known GW events. The project is designed as a distributed, open-source, citizen science initiative, where geographically separated users collectively log timing anomalies, cross-correlate with official GW alerts, and analyze results using machine learning. We outline the theoretical motivation, architecture, expected challenges, and roadmap.**

***Index Terms*—Gravitational waves, citizen science, distributed computing, artificial neural networks, weak field approximation, timing stability.**

I. Introduction

The direct detection of gravitational waves (GWs) by LIGO and Virgo marked the beginning of gravitational wave astronomy. These instruments are sensitive to spacetime strains on the order of 10^{-21}, a scale far beyond everyday measurement technologies. However, computing systems—whose performance depends critically on nanosecond-level clock precision—may serve as unconventional probes if timing anomalies can be correlated across multiple independent systems.

This proposal investigates whether predictable computational workloads can serve as timing baselines for auxiliary GW monitoring. Unlike interferometric detectors, which are optimized for strain sensitivity in the 10 Hz–10 kHz band, our system targets lower-frequency ranges (0.1 Hz–10 Hz), where subtle timing perturbations may leave statistical imprints in computation throughput.

II. Theoretical Motivation

A gravitational wave in the weak-field approximation is represented as:

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}, \quad |h_{\mu\nu}| \ll 1, \tag{1}$$

where $h_{\mu\nu}$ are the perturbations propagating at the speed of light.

The fractional change in proper time is approximately:

$$\frac{\Delta t}{t} \sim h. \tag{2}$$

Although such effects are minuscule, GHz-scale oscillators in CPUs and GPUs execute billions of operations per second. Thus, even sub-nanosecond variations, if coherently correlated across distributed systems, may be statistically measurable.

III. System Architecture

The proposed system has three major components:

1) **Local Monitoring Client:** Runs deterministic ANN workloads and computational benchmarks. When idle, it listens for GW alerts from LIGO/Virgo APIs.
2) **Event Trigger Mode:** Upon receiving a GW alert, the system requests user permission to shift all resources into a dedicated logging mode. All nonessential processes are paused or idled. An ultra-stable computational workload is executed with predicted operations per second (per core), and deviations are logged.
3) **Central Correlation Server:** Collects logs from distributed users, aligns them with official GW events, and applies machine learning classifiers to identify genuine coincidences.

A. Flowchart

Figure 1 illustrates the workflow.

IV. Methodology

A. Dummy ANN Workloads

We construct cascaded artificial neural networks with fixed architectures and dummy inputs/outputs. The computational demand is highly predictable, allowing per-core operations/sec to be estimated under ideal conditions.

B. Ultra-Stable Logging Mode

During normal operation, the program remains idle. Upon a GW event trigger, the program requests explicit user permission to suspend nonessential processes. This maximizes stability and minimizes interference. A high-intensity benchmark workload is run, and results are compared against baseline measurements.

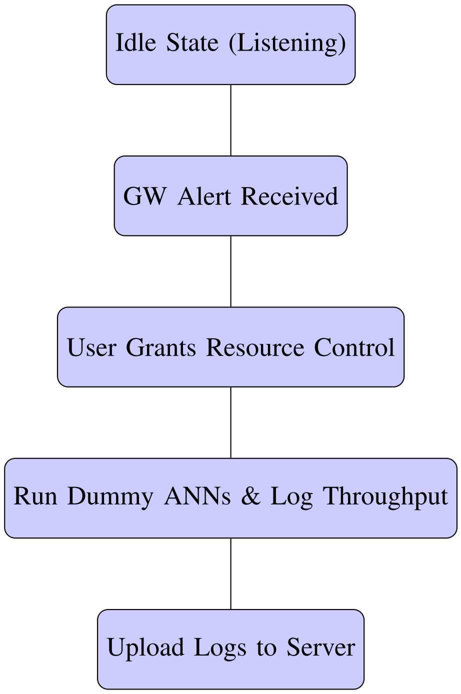

Fig. 1. Workflow of local client operation in response to a GW event.

C. Distributed Correlation

Individual noise sources (thermal drift, OS scheduling jitter) dominate single-system measurements. However, if many geographically separated systems report synchronous anomalies, cross-correlation with GW observatory data strengthens the signal-to-noise ratio.

V. Challenges and Limitations

- Strain amplitudes ($h \sim 10^{-21}$) are orders of magnitude below CPU jitter.
- Thermal, electrical, and OS-level noise sources may mask GW effects.
- Large-scale statistical methods and coincidence analysis are essential.

VI. Citizen Science Framework

We envision the project as an open-source initiative hosted on GitHub. Contributions include:

- **Client Software:** Python/C++ applications with logging modules.
- **Server Infrastructure:** Cloud-based aggregation and ML pipelines.
- **User Engagement:** Visualization dashboards, educational outreach, and community forums.

VII. Roadmap

1) **Phase I (0–6 months):** Prototype ANN workload + logging, integrate LIGO/Virgo alert API.
2) **Phase II (6–12 months):** Build distributed server, recruit pilot participants.
3) **Phase III (12–24 months):** Scale to 1000+ users, implement ML-based anomaly detection, publish results.

VIII. Conclusion

Although direct detection of GWs via computing systems is unlikely due to noise dominance, this project provides a unique citizen-science approach. It can complement large observatories, generate valuable datasets, and foster public engagement in GW research.

Acknowledgments

We thank the open-source community and contributors for their participation in citizen-driven gravitational wave science.

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