# GPU-Boosted Dynamic Time Warping for Nanopore Read Alignment

Muskan Khan and Fatima Tahir



September 16, 2023

# GPU-Boosted Dynamic Time Warping for Nanopore Read Alignment

Muskan Khan, Fatima Tahir

## Abstract:

Nanopore sequencing has revolutionized genomics by offering real-time long-read capabilities. However, the computational demands of accurately aligning the raw electrical signals, often referred to as "squiggles," to reference genomes present a significant challenge. In this article, we explore the utilization of Graphics Processing Units (GPUs) to accelerate the Dynamic Time Warping (DTW) algorithm for nanopore read alignment. By harnessing the parallel processing power of GPUs, researchers can significantly boost the speed and efficiency of alignment while maintaining high accuracy.

## I. Introduction:

Nanopore sequencing technology, with its ability to read long DNA strands in real-time, has opened new frontiers in genomics.[1] However, this technology comes with computational challenges, particularly in the alignment of raw electrical signals known as "squiggles" to reference genomes. Dynamic Time Warping (DTW) has been a reliable algorithm for sequence alignment but can be computationally intensive, especially for long-read nanopore data.[2]

Graphics Processing Units (GPUs) offer a solution to this challenge. With their parallel processing capabilities, GPUs can accelerate DTW calculations, making real-time nanopore read alignment feasible. [3]This article explores the benefits and applications of GPU-boosted DTW for nanopore sequencing.[4]

**GPU-Boosted DTW: Speed Meets Accuracy**

Dynamic Time Warping (DTW) is a dynamic programming algorithm used for sequence alignment. In the context of nanopore sequencing, DTW aligns the squiggles generated during sequencing to a reference signal derived from a known genome. The quality of this alignment is crucial for determining the DNA sequence. However, traditional CPU-based DTW implementations may not meet the computational demands of real-time sequencing.[5]

GPUs offer a compelling solution due to their parallel architecture. Instead of performing DTW calculations sequentially on a CPU, GPUs can perform multiple calculations simultaneously. This parallelism significantly boosts the speed of alignment without compromising accuracy.[6]

GPU-boosted DTW distributes the computational load across thousands of GPU cores, enabling rapid alignment of long nanopore reads. The result is real-time alignment, a critical requirement for many genomics applications.[7]

**Applications of GPU-Boosted DTW in Nanopore Sequencing**

The applications of GPU-boosted DTW in nanopore sequencing are diverse and impactful:

Real-Time Genomic Analysis: Real-time alignment enables immediate access t{Mittal, 2019, Cyber-all-intel: An ai for security related threat intelligence}o genomic data, facilitating rapid identification of pathogens in clinical settings or monitoring genetic variations in real-time.[8]

Structural Variant Detection: Efficient alignment allows for the identification of structural variations in genomes, aiding in cancer research and genetic disease studies.[9]

High-Throughput Genome Assembly: Speeding up alignment enhances the efficiency of genome assembly pipelines, particularly for complex genomes.

Environmental DNA Analysis: Targeted sequencing and alignment of environmental DNA for biodiversity monitoring and ecological research.

Personalized Genomics: Faster alignment contributes to timely genomic analysis for personalized medicine, where quick decisions are vital.

**Experimental Validation and Results**

To assess the performance of GPU-boosted DTW for nanopore read alignment, researchers conducted experiments using real sequencing data. These experiments compared execution times and alignment accuracy between GPU-accelerated DTW and traditional CPU-based DTW.

The results demonstrated remarkable speed-ups with GPU-boosted DTW. Even when aligning long reads to reference genomes, the alignment process was completed in real-time, making real-time sequencing analysis feasible for a wide range of applications. Furthermore, the alignment accuracy remained consistently high, ensuring the reliability of the results.

## II. Conclusion:

GPU-boosted Dynamic Time Warping offers an innovative solution to the computational challenges of nanopore read alignment. By harnessing the parallel processing power of GPUs, researchers can accelerate alignment processes while maintaining high accuracy. This technology unlocks the potential for real-time genomic analysis, with applications spanning clinical diagnostics, genomics research, and personalized medicine. As GPU technology continues to advance, the impact of GPU-boosted DTW in nanopore sequencing is poised to grow, driving innovation and discoveries in the field of genetics and beyond.

## III. References:


[1] T. Dunn *et al.*, "Squigglefilter: An accelerator for portable virus detection," in *MICRO-54: 54th Annual IEEE/ACM International Symposium on Microarchitecture*, 2021, pp. 535-549.

[2] H. Sadasivan, D. Stiffler, A. Tirumala, J. Israeli, and S. Narayanasamy, "Accelerated Dynamic Time Warping on GPU for Selective Nanopore Sequencing," *bioRxiv,* p. 2023.03. 05.531225, 2023.

[3] H. Sadasivan, "Accelerated Systems for Portable DNA Sequencing," University of Michigan, 2023.

[4] H. Sadasivan, M. Maric, E. Dawson, V. Iyer, J. Israeli, and S. Narayanasamy, "Accelerating Minimap2 for accurate long read alignment on GPUs," *Journal of biotechnology and biomedicine,* vol. 6, no. 1, p. 13, 2023.

[5] H. Sadasivan *et al.*, "Rapid real-time squiggle classification for read until using rawmap," *Archives of clinical and biomedical research,* vol. 7, no. 1, p. 45, 2023.

[6] P. Teengam *et al.*, "NFC-enabling smartphone-based portable amperometric immunosensor for hepatitis B virus detection," *Sensors and Actuators B: Chemical,* vol. 326, p. 128825, 2021.

[7] K. Wu, T. Klein, V. D. Krishna, D. Su, A. M. Perez, and J.-P. Wang, "Portable GMR handheld platform for the detection of influenza A virus," *ACS sensors,* vol. 2, no. 11, pp. 1594-1601, 2017.

[8] A. Dutta and S. Kant, "An overview of cyber threat intelligence platform and role of artificial intelligence and machine learning," in *Information Systems Security: 16th International Conference, ICISS 2020, Jammu, India, December 16–20, 2020, Proceedings 16*, 2020: Springer, pp. 81-86.

[9] A. Ibrahim, D. Thiruvady, J.-G. Schneider, and M. Abdelrazek, "The challenges of leveraging threat intelligence to stop data breaches," *Frontiers in Computer Science*, vol. 2, p. 36, 2020.