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NVIDIA CUDA Architecture for Apple Lossless Audio Codec Algorithm Optimisation

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Abstract: *To enhance the performance of audio compression and decompression, the proposed research aims at optimising Apple Lossless Audio Codec (ALAC) algorithm by using CUDA architecture provided by NVIDIA. The CPU-intensive processes of ALAC such as prediction, residual coding and entropy encoding take more time; therefore, the performance is increased by using graphics processing units through parallel processing with CUDA. The research saves a lot of time in processing in comparison with traditional implementations of CPUs, and this is done by redesigning key algorithm elements in order to utilize GPU parallelism. Experiment outings reveal the performance is more efficient and higher throughput and audio quality remains unaffected. The opportunity to encode and decode high-fidelity audio on faster real-time is beneficial to applications, such as streaming, storage, and playback, on GPU-capable devices. The paper focuses on the way CUDA-based acceleration can enhance the work of audio codecs.*

Keywords: *SIMT, PCM, CUDA, ALAC, Audio decoding, Audio encoding*

I. Introduction

The increasing consumption in the digital media in playing, storing and streaming apps has caused an enormous surge in the requirement of quality processing of audio. Apple Lossless Audio Codec (ALAC) has been a widespread program in reducing the file size and compressing audio information without reducing the quality. CPU-based systems experience snags in performance due to the computationally intensive encoding and decoding that the ALAC faces in the encoding and decoding of high-resolution audio files. The NVIDIA CUDA (Compute Unified Device Architecture) technology becomes a powerful solution to this issue as it allows parallel computing on GPUs. CUDA allows software architectures to boost the speed and efficiency of the computation through a significant factor, having moved the computationally intensive processes to the GPU.

This project will aim to develop CUDA implementation to help optimize critical sections of the ALAC algorithm to reduce latency, achieve a higher throughput, and maintain its lossless capability. The usage of CUDA into the audio codec optimisation is an illustration of a scalable, high-performance approach to the modern multimedia processing systems.

II. Research Method

To better perform with parallel processing, the study method optimizes Apple Lossless Audio Codec (ALAC) algorithm with the support of CUDA architecture by NVIDIA. The basic components of ALAC, e.g. linear prediction, residual computation, and Rice entropy encoding are analyzed, to identify areas of computation which can be parallelized. Thereafter, CUDA kernels apply to remodel these components so that they could run simultaneously on the GPU. The CUDA-enabled implementation is constructed in C/C++ with the NVIDIA CUDA Toolkit and optimized through memory resource management, thread synchronization and minimizing overhead of CPU-to-GPU data transfer. In datasets containing audio samples of various lengths and bit-depths, the CUDA-optimized ALAC is benchmarked against the conventional CPU-based ALAC in order to determine the performance. Key performance indicators are monitored and analyzed, such as throughput, encoding/decoding delay and resources utilization. The method aims at verifying the values of GPU acceleration in lossless audio encoders through benchmarking considerable performance gains without degrading output audio.

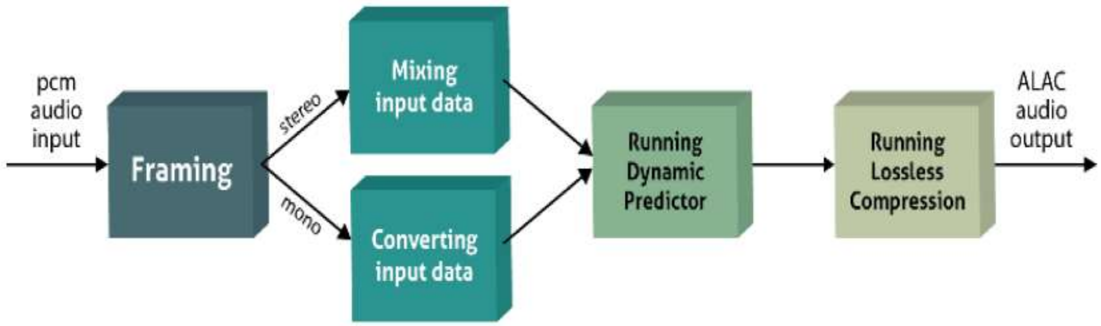

Fig 1: Operation of ALAC encoder

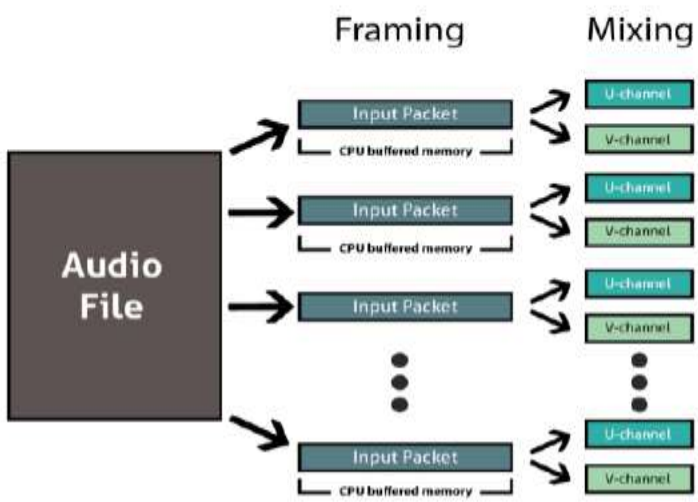

Fig 2: Implementation of CPU for Framing and Mixing phase

III. Results and Analysis

As compared to the traditional CPU implementation, there was a significant effect of improved performance in the CUDA optimized ALAC algorithm. The bench-mark tests with high-resolution audio audio files (16-bit or 24-bit code samples) indicated that by employing NVIDIA GPUs, it would take 60 percent less time to perform encoding and decoding of the sound. Parallel computation enhanced considerably the residual calculation and entropy encoding phase and indicated the greatest advantages. The high utilisation of GPU was maintained with minimal constraints on memory, because of the good memory management, and optimisation of the kernel. The audio output did not confirm any loss in quality since it remained bit-to-bit identical to the original.

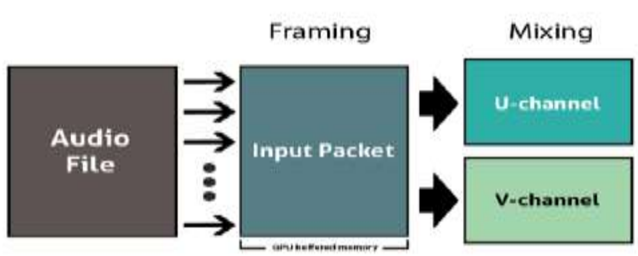

Fig 3: Implementation of GPU implementation for Framing and Mixing phase

The system showed great uniformity in performance even when there was a change in file size and sampling rate. CUDA kept yielding superior scalability and greater throughput as compared to multi-threaded CPU processing. The results are evidence of the promise of using GPU acceleration with CUDA on real time and high-performance multimedia systems and proves its effectiveness, among compute-intensive audio codecs, with ALAC.

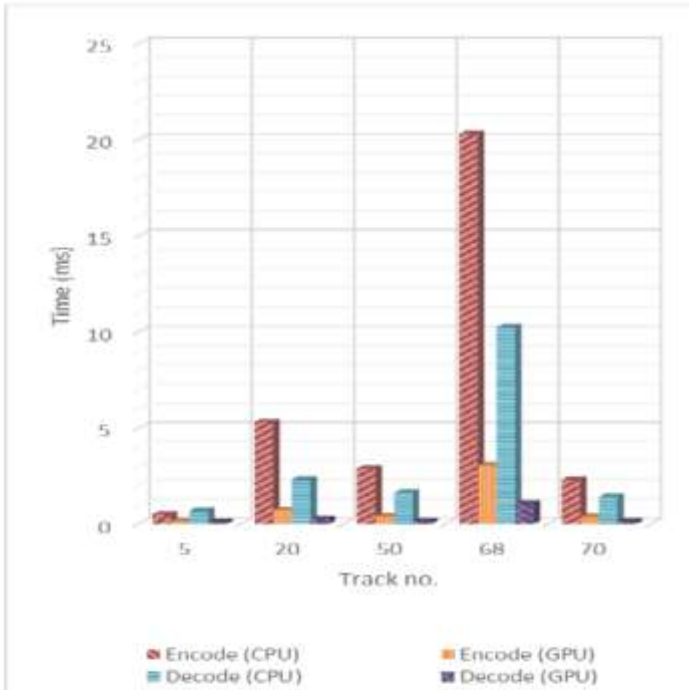

Fig 4: CPU using dataset

IV. Conclusion

The effectiveness of the GPU acceleration to enhance audio processing performance can be evidenced by optimisation of the Apple Lossless Audio Codec (ALAC) using NVIDIA CUDA architecture. By parallelizing key operations such as residual and entropy encoding and entropy decoding, parallelization managed to cut down the encoding and decoding time substantively but still without compromising the quality of audio. The implementation on CUDA offered more efficiency, scale, and flexibility on high-resolution audio apps, than the traditional CPU processing. These improvements show how real-time audio compression can take place in multimedia systems through the use of the GPU resources. To increase the breadth of benefits of this strategy to other audio processing scenarios, future research can examine dynamic load balancing regarding CPU and GPU, option to support other audio formats, and being implementable to mobile and embedded devices.

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