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Intelligent Fractal Video Compression and Super-Resolution Zooming

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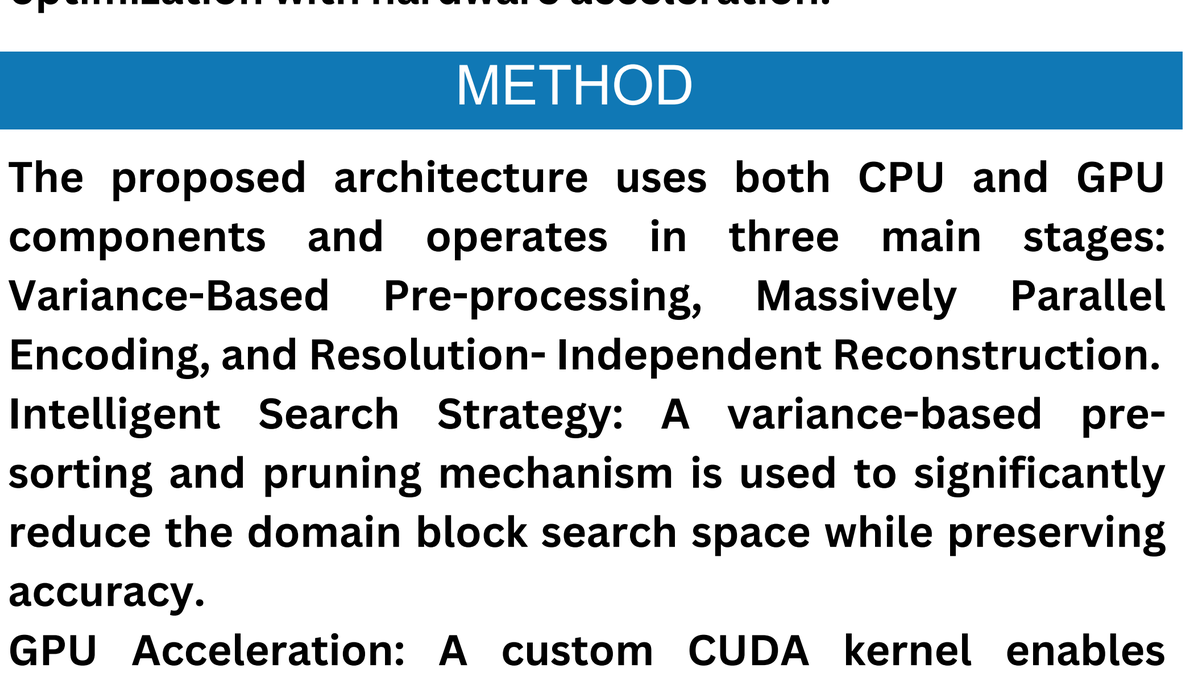
INTRODUCTION & AIM

- The rapid growth of digital video services has increased the demand for effective and scalable video compression.
- Standard transform-based codecs (like H.264/HEVC) are resolution-dependent and often suffer from pixelation artifacts when magnified.
- Fractal Image Compression (FIC) offers the advantage of resolution independence, allowing for deep zooming without standard pixelation artifacts.
- However, traditional FIC requires a brute-force block matching process with a high computational cost of $O(N_R \times N_D)$, where N_R and N_D represent the number of range and domain blocks, respectively.
- **Aim:** To propose a high-performance framework that overcomes FIC bottlenecks by combining algorithmic optimization with hardware acceleration.

METHOD

- The proposed architecture uses both CPU and GPU components and operates in three main stages: Variance-Based Pre-processing, Massively Parallel Encoding, and Resolution- Independent Reconstruction.
- Intelligent Search Strategy: A variance-based pre-sorting and pruning mechanism is used to significantly reduce the domain block search space while preserving accuracy.
- GPU Acceleration: A custom CUDA kernel enables massively parallel affine block matching across thousands of GPU threads simultaneously.



Process Flow Diagram of the System Model

RESULTS & DISCUSSION

- All evaluations were performed on a system equipped with an NVIDIA T4 GPU.
- Speed & Efficiency: The intelligent GPU strategy achieved a 10-fold reduction in average operations per frame, dropping from 1,67,200 to 19,360 domain checks. This resulted in processing times of 0.04 seconds per frame, making it 46 times faster than the basic CPU system.
- Quality: The GPU approach achieved a Peak Signal-to-Noise Ratio (PSNR) of 32.50dB, a noticeable improvement over the CPU's 26.83dB.
- Deep Zooming (Super-Resolution): The system successfully rendered zoomed outputs at 2.0x and 3.0x resolutions, maintaining an average PSNR above 31dB while achieving strong compression ratios of 12.1:1 and 8.7:1 respectively.

Metric	Original (CPU)	Intelligent (GPU)
PSNR (dB)	26.83	32.50
Time/Frame (s)	1.96	0.04
Ops/Frame (Total Domain Checks)	1,67,200	19,360
Raw Video Size (MB)	13.43	13.43
Comp. Data Size (MB)	0.73	0.79
Compression Ratio	18.3:1	17.1:1

CPU VS. GPU Performance and Compression Ratio

CONCLUSION

- By combining a variance-based heuristic with a highly optimized parallel GPU kernel, the system achieves real-time video encoding latency with high reconstruction fidelity.
- The research demonstrates that optimized fractal encoding pipeline deployment on GPU hardware provides a lightweight accelerated solution for video compression and super-resolution applications that need high performance in limited bandwidth environments.

REFERENCES

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