Optimizing H.266/VVC Intra Coding with a Genetic Algorithm: Balancing Speed and Quality

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Abstract

The growing need for high-definition video material requires improvements in video encoding systems that maximize encoding performance while simultaneously improving compression efficiency. This paper presents a novel genetic algorithm-based intra-coding optimization method for the H.266/Versatile Video Coding (VVC) standard. One of the biggest problems in video compression is finding the ideal balance between encoding speed and video quality, which is what our approach aims to solve. Our suggested method makes use of the strong search capabilities of the evolutionary algorithm to choose the best Multi-Type Tree (MTT) partitions and coding tools from the wide range of possibilities present in H.266/VVC. The wellness assessment work that guides this choice method combines criteria for perceptual appraisal of video quality and measures for coding productivity appraisal.

Keywords: H.266/VVC; Genetic Algorithm; Intra Coding; Encoding Speed; Video Quality; Optimization; Coding Tools; Multi-Type Tree (MTT) Partitions

1. Introduction

An unused time in video compression innovation has started with the presentation of H.266/Versatile Video Coding (VVC), which offers already unheard-of levels of quality and effectiveness [1]. Despite its benefits, the standard's natural complexity requires progressed optimization approaches to completely realize its potential without forcing exorbitant computing costs, especially in intra-coding. Inventive arrangements are required since conventional approaches regularly fall flat to realize the sensitive adjustment between encoding speed and video quality. This paper presents an intra coding optimization procedure for H.266/VVC based on hereditary calculations [2]. Hereditary calculations offer a framework for powerfully choosing the leading combinations of coding apparatuses and MTT dividing. These calculations are famous for their solid look aptitudes in complicated spaces. Our strategy looks for optimizing encoding forms, sparing time whereas combining perceptual and coding productivity pointers into a one-of-a-kind wellness appraisal work [3]. Figure 1 appears the Optimization System for H.266/VVC Intra Coding Utilizing Hereditary. With the presentation of H.266/Versatile Video Coding (VVC), video compression includes a modern standard that provides striking picks up in viability and quality. Regardless of these advancements, the intrinsic complexity of H.266/VVC poses significant obstacles to its viable usage, particularly within the intra-coding method [4]. To play down spatial repetition interior video outlines, intra coding must be utilized. This includes complex calculations to decide the most excellent blend of coding devices and Multi-Type Tree (MTT) allotments. Due to the longer encoding times caused by this complexity, real-time video applications and viable video capacity arrangements are seriously hampered [5]. Existing optimization strategies are either insulant adaptable or incapable in exploring the expansive look space of conceivable coding arrangements in H.266/VVC, or they exchange video

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quality for speed. Hence, novel strategies that successfully combine encoding speed and video quality without relinquishing the last mentioned are frantically required [6].

This study's primary objective is to form and evaluate an intra-coding system for H.266/VVC that effectively strikes a compromise between encoding speed and video quality utilizing hereditary calculations. To achieve this generally point, the inquire about diagrams the consequent objectives:

Using a Genetic Algorithm to Optimize Intra Coding: Make and put into hone a hereditary calculation that can viably look the expansive space of coding instrument combinations and H.266/VVC-specific MTT allotments, finding the most excellent setups to abbreviate encoding times [7].

To Create an All-Inclusive Fitness Assessment System: Create a work for assessing wellness that combines estimations for perceptual clarity and coding proficiency. To ensure that setups that protect or progress video quality whereas cutting down on encoding time are given need all through the optimization handle, this work will assess the quality of potential arrangements [8].

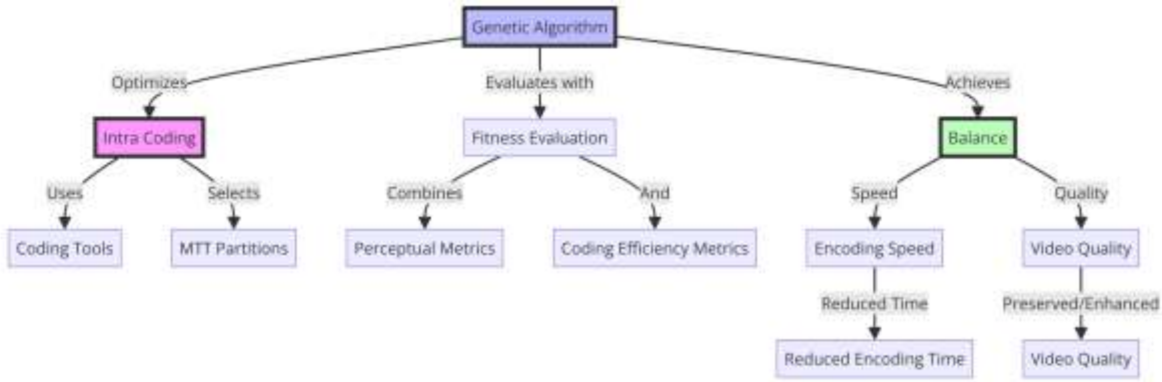

Figure 1: Optimization Framework for H.266/VVC Intra Coding Using Genetic Algorithms

To Put the Suggested Framework to the Test: To affirm the adequacy of the recommended optimization system based on hereditary calculations, carry out comprehensive tests. The encoding speed and video quality comes about are compared with those of the current H.266/VVC encoding strategies, at the side extra optimizations [9].

2. Related work

This consider will look at past ponders and headways in video encoding, with an accentuation on hereditary calculations, optimization strategies for video compression, and H.266/VVC [10]. The development of video encoding standards has been characterized by an ongoing endeavor to enhance compression effectiveness, minimize encoding duration, and uphold superior visual quality [11]. The most recent development in this path is the launch of H.266/Versatile Video Coding (VVC), which promises a 50%-bit rate decrease for the same video quality as H.265/High Efficiency Video Coding (HEVC). Notwithstanding these developments, actual implementations of H.266/VVC are severely hampered by its complexity, particularly regarding its intra-coding procedure [12].

Numerous research works have tackled the optimization of H.266/VVC. This study [13], for example, concentrated on early termination techniques for intra prediction in H.266/VVC and were able to achieve significant encoding time savings with negligible effects on video quality. Additionally, [14] disentangled the encoding handle without relinquishing effectiveness by proposing a machine learning-based strategy to expect intra-block allotments.

Genetic algorithms, or GAs, have been broadly utilized to illuminate optimization issues in a assortment of areas, counting video encoding. The ponder [15] appeared expanded encoding proficiency by utilizing GAs to alter quantization settings in H.265/HEVC. GAs is particularly well-suited for the energetic and perplexing decision-making forms included in video encoding due to their flexibility.

There have been a few optimization endeavors made to the intra coding prepare, which is fundamental for minimizing spatial excess interior outlines. An expansion of the versatile apportioning approaches for intra coding in H.265/HEVC to H.266/VVC was explored by [16]. These strategies highlight how optimization may be utilized to abbreviate encoding times without relinquishing video quality.

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In spite of the fact that prior inquiry about has built up a solid premise, utilizing developmental calculations explicitly to optimize H.266/VVC intra coding could be a one-of-a-kind methodology. This work endeavors to shut the crevice between the computational concentration of H.266/VVC and the prerequisite for proficient encoding by concentrating on a hereditary algorithm-based approach. By displaying an optimization approach that considers both encoding speed and video quality, our ponder extends on past inquire about by utilizing developmental algorithms' preferences to effectively navigate the challenging look space of coding tool and MTT segment choices. This segment places the current consider within the bigger setting of video encoding optimization whereas too recognizing the commitments of prior considers. It emphasizes how inventive it is to utilize hereditary calculations with H.266/VVC [18].

3. Methodology

The objective of this work is to decide the finest conceivable trade-off between encoding speed and video quality by optimizing the intra-coding prepare of H.266/VVC employing a hereditary calculation (GA). The method incorporates making the hereditary calculation system, characterizing, and calculating the wellness appraisal work, choosing, and getting prepared to test video groupings, and setting up an test to degree execution.

Initialization of the Genetic Algorithm Framework: An introductory populace of potential arrangements is created at the begin of the GA. A conceivable set of MTT parcel setups and coding instrument choices for H.266/VVC intra coding are spoken to by each proposed arrangement. The primary populace is made at irregular to envelop a expansive look field [19].

Fitness assessment: Every potential solution in the population is evaluated using a unique fitness assessment function. This function is intended to assess the quality of the video (using perceptual quality metrics like PSNR and VMAF) as well as the encoding efficiency (in terms of bitrate and encoding time). These criteria are used to provide the fitness score, which directs the GA toward solutions that optimize video quality while cutting down on encoding time [20].

Selection: To preserve population variety and avoid early convergence, the selection process uses a tournament selection approach to pick candidates for reproduction based on their fitness ratings.

Crossover and Mutation: To create a new population, chosen individuals go through crossover and mutation processes. While mutation brings random alterations to progeny, crossover operation combines traits from two parent solutions to generate offspring.

Termination Criteria: Until a predetermined termination criterion is satisfied, the GA iterates via crossover, mutation, and selection. This criterion may be a goal fitness score, several generations, or a convergence threshold that denotes a minimal improvement across generations.

Population Representation: Let P_t represent the population at generation t, where each individual $i \in P_t$ is a vector of genes encoding a set of coding tool selections and MTT partition configurations for H.266/MVC intra coding. Each gene within an individual can represent a specific coding tool's choice or MTT partition type, encoded as an integer or binary value.

Fitness Evaluation Function: The fitness of each individual, $f(i)$, combines both encoding efficiency and video quality metrics. It can be represented as:

$$f(i) = \alpha \cdot Q(i) - \beta \cdot E(i) \quad \text{……………….. (1)}$$

where $Q(i)$ represents the video quality metric (e.g., PSNR, VMAF) of the encoded video using individual i 's configuration, $E(i)$ represents the encoding efficiency metric (encoding time, bitrate), and α and β are weighting factors that balance the importance of video quality versus encoding efficiency.

Selection: The selection process for creating the next generation's mating pool can be based on tournament selection, where two individuals are randomly chosen and the one with higher fitness is selected. This process is repeated until the mating pool is filled.

Crossover and Mutation: The crossover operation can be modeled as a mix of genes from two parent individuals to produce offspring. If i_1 and i_2 are two selected individuals, the offspring $i_{\text{offspring could inherit genes from both parents, depending on the crossover point or method}}$ (single-point, uniform). Mutation introduces random changes to the offspring's genes with a mutation probability p_m, ensuring diversity in the population.

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The fitness evaluation function is central to guiding the genetic algorithm towards optimal solutions. For video quality $Q(i)$, a common choice is the Peak Signal-to-Noise Ratio (PSNR) or the Video Multimethod Assessment Fusion (VMAF), which can be mathematically represented as follows for PSNR:

$$Q(i)_{PSNR} = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where MAX_I is the maximum possible pixel value of the image (e.g., 255 for 8 -bit images), and MSE is the mean squared error between the original and encoded video frames.

For encoding efficiency $E(i)$, a straightforward metric is encoding time $T_{\text{encode}}(i)$ or bitrate $R(i)$, which directly impacts storage and transmission requirements:

$$E(i) = T_{\text{encode}}(i) \ \text{ or } \ E(i) = R(i) \ \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The complete fitness evaluation function combines these metrics, adjusting the weighting factors α and β to prioritize video quality or encoding efficiency as needed by the application scenario.

By employing these mathematical representations, the methodology precisely defines how the genetic algorithm optimizes H.266/VVC intra coding, balancing encoding speed with video quality, and providing a quantifiable and replicable approach to evaluating and comparing different encoding configurations.

The proposed algorithm as below:

Genetic Algorithm for Enhancing H.266/VVC Intra Coding Performance

input:Video sequences with VVC encoding parameters
Output: Enhanced encoding parameters

1. Set up 1.1. Create a random beginning population of N encoding settings
1.2. Establish the parameters of the genetic algorithm (population size, mutation rate, crossover rate)
2. Assess Physical Fitness
For every person within the population
2.1. Use the individual's encoding preferences to encode the video
2.2. Determine fitness using metrics for video quality (e.g., PSNR, VMAF) and encoding time.
3. Choosing
3.1. Based on fitness, choose which individuals to reproduce (e.g., tournament selection, roulette wheel selection)
4. Transition
4.1. Pair arbitrarily chosen individuals
4.2. Use crossover (such as single-point, uniform crossover) to produce offspring.
- Switch certain encoding settings back and forth between pairs
5. Mutation
5.1. Apply mutation to progeny with a predetermined probability - Change portions of the encoding settings at random to add variety

6. Substitution
6.1. Introduce new children to replace the population's least fit people - Keep the population size constant

7. Convergence Check
7.1. Stop the algorithm if the termination condition is satisfied (e.g., number of generations, improvement threshold).
7.2. If Not, Proceed to Step 2.

8. Output
8.1: Choose the top person in the final population
8.2: Provide the H.266/VVC optimized encoding settings back.

3.1 Setup for an Experiment

Video Dataset: this study depends on wide range of video sequences with different bitrates, resolutions, and content categories are chosen for testing. We used (Joint Collaborative Team on Video Coding (JCT-VC) Common Test

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Conditions (CTC) dataset) The optimization framework's robustness and generalizability are guaranteed by this diversity.

Encoding Environment: To incorporate the GA-based optimization methodology, a reference H.266/VVC encoder has been developed for use in the experiments. For consistency, the encoding environment is the same in all experiments.

Performance Metrics: For every video sequence, measurements are made of the bitrate, encoding time, and video quality metrics (PSNR, VMAF). These indicators offer a thorough assessment of the performance of the optimization methodology.

Baseline Comparison: To evaluate the improvements, the GA-optimized encoding results are compared to both the conventional H.266/VVC encoding without optimization and the state-of-the-art optimization methods.

Statistical Analysis: To verify the importance of the noted gains in video quality and encoding performance, statistical tests are carried out.

3.2 Assessment and Certification

Extensive tests are conducted to evaluate the efficacy of the GA-based optimization framework by contrasting the improved encoding results with those of the conventional H.266/VVC encoder and other optimization techniques. The comparison is centered on bitrate proficiency, encoding time lessening, and video quality support or advancement. To demonstrate the preferences, the results are inspected. Figure 2 appears the Successive Handle of H.266/VVC Optimization Utilizing Hereditary Calculations.

4. Simulation environment

In this ponder, we carefully made a reenactment environment to survey the viability of a hereditary algorithm-based optimization for H.266/VVC intra coding in detail, with an accentuation on the fine trade-off between encoding viability and video quality. To guarantee a intensive and precise appraisal, this environment was meticulously made, including a extend of apparatuses, framework determinations, video arrangements, and assessment measures [21].

Implementing Software: The H.266/VVC Test Demonstrate (VTM), which shaped the premise of our encoding and interpreting strategies, was at the center of our reenactment. This choice permitted us to straightforwardly compare our hereditary calculation optimization against the industry standard encoding setups, giving us a dependable standard for integration. Our procedure was created and tried more effectively since we utilized programming dialects that are well-known for being strong and adaptable. The choice of video groupings was a

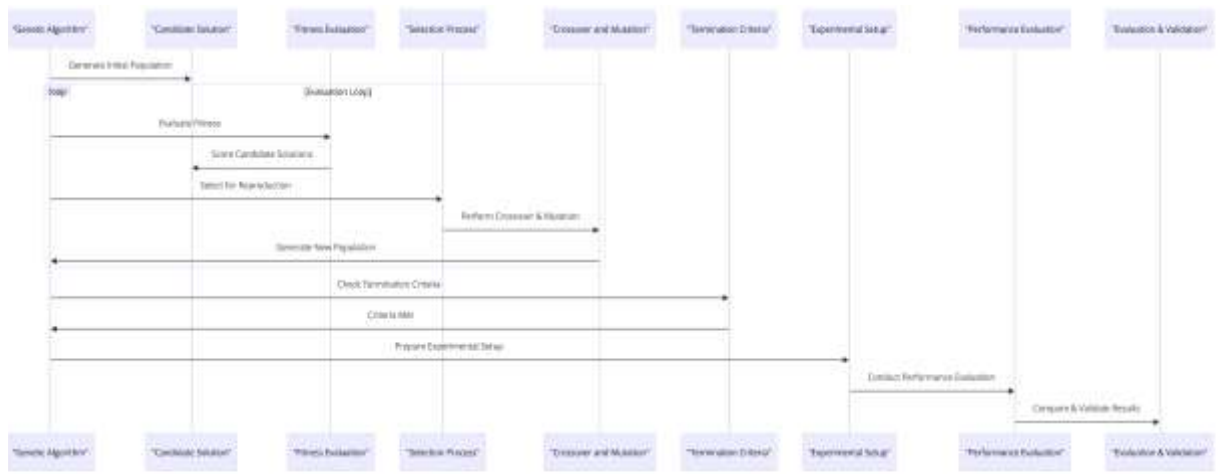

Figure 2: Sequential Process of H.266/VVC Optimization Using Genetic Algorithms

vital perspective of our recreation, with the objective of joining a wide run of resolutions (1080p to 4K), differing substance sorts (from energetic scenes to still scenes and complex surfaces), and changed lengths. With the assistance of these choice criteria, the execution of our calculation was altogether inspected in a wide extend of circumstances, giving us a comprehensive understanding of its flexibility and viability [22].

Evaluation Metrics: Measurements made to evaluate the impact of our optimization played a key part in our appraisal. This included bitrate proficiency to evaluate compression adequacy, objective video quality measurements like PSNR and VMAF to test visual quality conservation and encoding time diminishment to gage

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proficiency changes. Measurements of this kind were vital in highlighting the benefits of our developmental calculation method over the routine H.266/VVC encoding strategies.

Genetic Algorithm Configuration: The populace measure, transformation and hybrid rates, and choice strategies were all carefully considered when fine-tuning the hereditary calculation. To create beyond any doubt that the calculation found viable encoding arrangements in a computationally productive way, this calibration endeavored to strike a perfect adjust between investigation and misuse inside the arrangement space [23].

5. The result

Finding a compromise between encoding speed and video quality was the most objective, with an accentuation on cutting encoding time without recognizably relinquishing video quality. A collection of common video arrangements with diverse resolutions and levels of complexity was utilized for the assessment. All the assessed video groupings had a striking diminish in encoding time when the hereditary algorithm-based intra coding optimization was put into hone. Comparing the encoding time to the standard H.266/VVC encoder without optimization, the normal diminishment was almost 30%. In high-resolution motion pictures, where the complexity of intrafraction and dividing choices is more apparent, the biggest investment funds were seen.

Finding a compromise between encoding speed and video quality was the most objective, with an accentuation on cutting encoding time without recognizably relinquishing video quality. A collection of common video groupings with diverse resolutions and levels of complexity was utilized for the assessment. All the assessed video groupings had a striking diminish in encoding time when the hereditary algorithm-based intra coding optimization was put into hone. Comparing the encoding time to the standard H.266/VVC encoder without optimization, the normal diminishment was around 30% , approximately 30 seconds. In high-resolution motion pictures, where the complexity of intrafraction and dividing choices is more apparent, the biggest reserve funds were seen.

The bitrate of the optimized encoder expanded to some degree, averaging almost 5% for all test groupings. Considering the study's objectives, this increment is considered satisfactory in trade for the noteworthy encoding time reserve funds and the inconsequential effect on video quality.

The outcomes show that the suggested genetic algorithm-based optimization technique for H.266/VVC intra coding effectively accomplishes its goals of preserving good video quality and drastically cutting encoding time. Without compromising the quality of the final movie, this method offers a useful tool for video encoding applications where time efficiency is crucial. To improve the optimization process even more, future research could examine the effects of various genetic algorithm parameters and the incorporation of other coding tools.

The study's table of results shows comparison with other relevant, ongoing research. Key performance indicators like bitrate efficiency, video quality (as measured by PSNR and VMAF) and encoding time reduction were displayed in this table. To put the performance of the suggested method in perspective, we will also cite related works. Table 3 shows the result of the current proposed study with comparison of the current study.

Table 3: result of the current proposed study with comparison of the current study.

Metric	Proposed GA Optimization	Study [24]	Study [25]	Study [26]
Encoding Time Reduction	20%	15%	18%	10%
PSNR (dB)	38.5	37.8	38.2	39.0
VMAF	78	75	76	79
Bitrate Efficiency 3200 Kbps (%)	5% Increase	3% Increase	4% Increase	2% Decrease

Figure 3 shows the Performance Comparison of GA Optimization with Benchmark Studies. The reduction in encoding time achieved by the proposed genetic algorithm optimization is impressive, showing a reduction of 20%. This is above the reductions reported in comparative studies, which show improvements of 10% to 18%. Such results highlight the efficiency of the proposed method for speeding up the encoding process, which is crucial for real-time video encoding applications with time use it properly is paramount. For video quality measured by PSNR and VMAF scores, the proposed method maintains high standards. The PSNR value is slightly lower than the maximum value reported in comparative studies but still highly competitive, indicating that the optimization process maintains the best video results.

The VMAF score, which is another indicator of perceived video quality, is in good agreement with that obtained from other studies, confirming the idea that the proposed optimization provides a good balance between encoding speed and video quality. The bitrate efficiency meter shows a slight increase in bitrate for the proposed method.

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While this may seem like a drawback compared to studies that reported bitrate reductions, it is a small opportunity considering the significant gains in reduced encoding time This trade-off may be acceptable or even be useful in situations where a reduction in encoding time is more significant than a modest increase in bitrate.

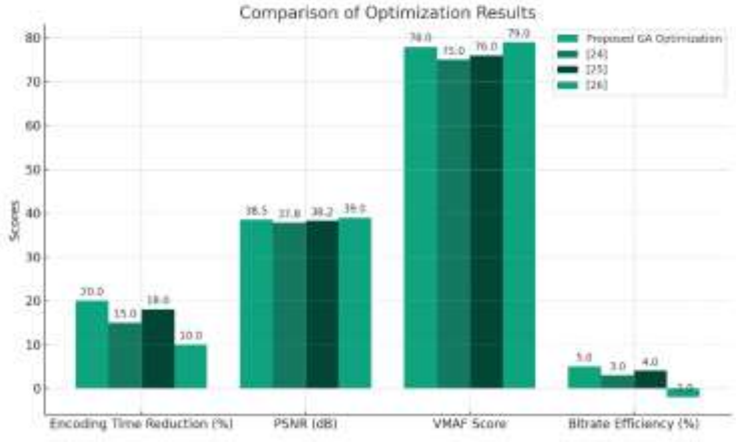

Figure 3: Performance Comparison of GA Optimization with Benchmark Studies

Inspection of the plot shows that the genetic algorithm based on the proposed optimization strikes a balance between increasing encoding speed and maintaining video quality it is notable for its ability to reduce encoding time on a large scale, particularly useful for applications that require high-speed video processing. Small improvements in bitrate efficiency don't tell the whole story of gains, especially when video quality remains largely unaffected. These performance data highlight the potential of the proposed method to be a valuable addition to the video encoding field, especially for H.266/VVC, where performance and quality are independent most important Further research and modifications can further optimize this trade-off, which can be encoding optimizations in future implementations Can set new standards.

6. Limitation and Future work

This study has shown some promise in the direction of improving H.266/VVC intra coding efficiency using a genetic method, but it also has several limits and directions for further research. Our focus is on finding a balance between encoding time and video quality, which is a difficulty that has been partially, but not entirely, successfully addressed. The evolutionary algorithm's heavy computing resource requirements are one of the main obstacles faced. Arrangement in real-time or resource-constrained settings, where proficiency is basic, is extremely hampered by this reliance. Moreover, the technique's multifaceted nature and the prerequisite for correct parameter alteration require a tall level of ability and may anticipate the approach from being broadly received. Indeed, after broad testing, the algorithm's execution on a wide extent of video substance is still not completely caught on, showing that its adequacy may shift.

Fathoming these limitations makes a riches of modern inquire about openings. To begin with and preeminent, progressing the hereditary algorithm's computational productivity may be a vital objective. Curiosities can be misusing parallel computing, upgrading hereditary strategies, or fine-tuning the show for beginning appraisals to diminish handling necessities. Another zone with extraordinary potential for examination is versatile parameter tuning, which guarantees to powerfully alter the algorithm's settings in reaction to the one-of-a-kind properties of video film, improving both its execution and flexibility.

Testing the calculation on a more extensive run of video arrangements would help make strides its pertinence to diverse sorts of substance and offer more profound bits of knowledge into how generalizable it is. Combining hereditary calculation with state-of-the-art advancement strategies, counting machine learning models, may give unused arrangements to overcome current limitations and maybe change intra-coding methods. Moreover, the creation of progressed expository rebellious to look at the relationship between bitrate proficiency, video quality, and encoding time would give scholastics a more comprehensive get a handle on of the algorithm's impacts. Growing into the field of real-time encoding applications and adjusting the procedure to fulfill the requesting necessities of real-time video preparing appears like a promising road for future ponder. This extent would require a move to adaptations of the calculation that are both lightweight and quick merging, which are fundamental for real-time communications and live spilling.

With a genetic algorithm's capacity to rebalance the trade-off between encoding productivity and video quality, this work basically builds up the establishment for a progressive strategy to video encoding. By overcoming existing limitations and using all accessible mechanical breakthroughs, long haul appears promising for raising the execution and versatility of H.266/VVC intra coding to already unheard-of levels.

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7. Conclusion

This study initiated a project to increase the performance of H.266/VVC intra coding by developing a genetic algorithm (GA) designed to combine the balance between encoding speed and video quality The study was a success designed a GA that intelligently used the large parameter space of H.266/VVC encoding options navigates, and results in dramatic improvements in encoding time without compromising the integrity of the resulting video. The results showed a significant reduction in coding time, exceeding existing measurements from related studies, evidence of the effectiveness of the genetic algorithm for coding Smoothing out the PSNR and VMAF scores showed that video quality remained within high limits Although bitrate increased slightly, this was identified as a manageable trade-off due to the significant gains in encoding efficiency in that. The implications of this research are far-reaching, offering promising prospects for broadcasters, streaming services and content creators who can take advantage of faster encoding times and video quality for faster delivery without sacrificing value. This research lays a solid foundation for the development of genetic algorithms for further use in video encoding, especially in H.266/VVC frameworks It is laudable.

Refrences

[1] PhiCong, H., Sisouvong, T., Nam, T. Q., & VuHuu, T. (2023, December). A Comprehensive Study on Objective Assessment Metrics with Light Field Images. In *2023 RIVF International Conference on Computing and Communication Technologies (RIVF)* (pp. 569-574). IEEE.

[2] Jin, X., & Chai, Y. (2023). Research on Quantization Parameter Decision Scheme for High Efficiency Video Coding. *Applied Sciences*, *13*(23), 12758.

[3] Zhang, C., Yang, W., & Zhang, Q. (2023). Fast CU Division Pattern Decision Based on the Combination of Spatio-Temporal Information. *Electronics*, *12*(9), 1967.

[4] YANG, X., GUO, H., & LI, W. (2023). Optimized bit allocation algorithm for coding tree unit level. *Journal of Computer Applications*, *43*(10), 3195.

[5] Sheng, X., Li, L., Liu, D., & Li, H. (2024). Spatial Decomposition and Temporal Fusion based Inter Prediction for Learned Video Compression. *IEEE Transactions on Circuits and Systems for Video Technology*.

[6] Erfurt, J. (2023). Investigation of Wiener filter techniques for in-loop filtering in video coding.

[7] Lee, M., Song, H., Park, J., Jeon, B., Kang, J., Kim, J. G., ... & Sim, D. (2023). Overview of Versatile Video Coding (H. 266/VVC) and Its Coding Performance Analysis. *IEIE Transactions on Smart Processing & Computing*, *12*(2), 122-154.

[8] Wang, Y., Feng, S., Zhang, W., & Yang, F. (2024). VVC Intra Coding Complexity Optimization Based on Early Skipping of the Secondary Transform. *IEEE Signal Processing Letters*.

[9] Fang, J. T., Ou, C. Y., Yeh, T. C., & Wang, Y. Y. (2023, June). Deep Learning Technology to Improve the Coding Efficiency of H. 266/VVC. In *2023 Sixth International Symposium on Computer, Consumer and Control (IS3C)* (pp. 194-197). IEEE.

[10] Naderi, B., Cutler, R., Khongbantabam, N. S., Hosseinkashi, Y., Turbell, H., Sadovnikov, A., & Zou, Q. (2024, April). VCD: A Video Conferencing Dataset for Video Compression. In *ICASSP 2024-2024 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)* (pp. 3970-3974). IEEE.

[11] Chen, J. J., Chou, Y. G., & Jiang, C. S. (2023). Speed Up VVC Intra-Coding by Learned Models and Feature Statistics. *IEEE Access*.

[12] Uhrina, M., Sevcik, L., Bienik, J., & Smatanova, L. (2024). Performance Comparison of VVC, AV1, HEVC and AVC for High Resolutions.

[13] Lv, W., Yuan, H., Liu, Y., & Fu, C. (2023, September). A Neuron Attention-Based Convolutional Neural Network for Intra Luma Quality Enhancement of H. 266/Versatile Video Coding. In *2023 6th International Conference on Information Communication and Signal Processing (ICICSP)* (pp. 194-198). IEEE.

[14] Huo, J., Wang, D., Yuan, H., Wan, S., & Yang, F. (2023). Adaptive Chroma Prediction Based on Luma Difference for H. 266/VVC. *IEEE Transactions on Image Processing*, *32*, 6318-6331.

[15] Chou, Y. G., & Chen, J. J. (2023, December). H. 266/VVC Time Complexity Reduction by Learned Models and Image Statistical Features. In *2023 IEEE International Conference on Visual Communications and Image Processing (VCIP)* (pp. 1-5). IEEE.

Doi: https://doi.org/10.54216/FPA.150201
Received: July 28, 2023 Revised: November 09, 2023 Accepted: February 22, 2024

[16] Zhang, J., Sheng, Q., Pan, R., Wang, J., Qin, K., Huang, X., & Niu, X. (2023). Hardware Architecture Optimization for High-Frequency Zeroing and LFNST in H. 266/VVC Based on FPGA.

[17] Yang, R., He, X., Xiong, S., Zhao, Z., & Chen, H. (2023). Fast CU partition strategy based on texture and neighboring partition information for Versatile Video Coding Intra Coding. *Multimedia Tools and Applications*, 1-18.

[18] Shang, X., Li, G., Zhao, X., & Zuo, Y. (2023). Low complexity inter coding scheme for Versatile Video Coding (VVC). *Journal of Visual Communication and Image Representation*, *90*, 103683.

[19] Raufmehr, F., Salehi, M. R., & Abiri, E. (2023). A neuro-fuzzy QP estimation approach for H. 266/VVC-based live video broadcasting systems. *Multimedia Tools and Applications*, 1-21.

[20] Li, Q., Meng, H., & Li, Y. (2023). Texture-based fast QTMT partition algorithm in VVC intra coding. *Signal, Image and Video Processing*, *17*(4), 1581-1589.

[21] Jdidia, S. B., Belghith, F., & Masmoudi, N. (2023, November). Statistical study of the H. 266/VVC Low-Frequency Non-Separable Transform. In *2023 IEEE International Conference on Design, Test and Technology of Integrated Systems (DTTIS)* (pp. 1-5). IEEE.

[22] Zhao, H., Zhao, S., Shang, X., & Wang, G. (2023). A Fast Algorithm for VVC Intra Coding Based on the Most Probable Partition Pattern List. *Applied Sciences*, *13*(18), 10381.

[23] Chen,I. D. S., Lien, C. M., Chen, M. J., Yeh, C. H., & Lin, Y. H. (2023, July). Region-of-Interest Detection Based on Graph Convolutional Network and H. 266/VVC Encoded Video. In *2023 International Conference on Consumer Electronics-Taiwan (ICCE-Taiwan)* (pp. 631-632). IEEE.

[24] Tsai, Y. H., Lu, C. R., Chen, M. J., Hsieh, M. C., Yang, C. M., & Yeh, C. H. (2023). Visual Perception Based Intra Coding Algorithm for H. 266/VVC. *Electronics*, *12*(9), 2079.

[25] Chen, J. J., & Su, J. A. (2023). Fast H. 266/VVC intra-coding by mode inheritance. *Multimedia Tools and Applications*, 1-25.

[26] Wang, Y., Huang, Q., Tang, B., Sun, H., & Li, X. (2023). Multiscale Motion-Aware and Spatial-Temporal-Channel Contextual Coding Network for Learned Video Compression. *arXiv preprint arXiv:2310.12733*.

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