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Software Update

Version [8.0] – [IV-PSNR: Software for immersive video objective quality evaluation]

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A R T I C L E I N F O

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Image quality assessment
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A B S T R A C T

This paper describes IV-PSNR v8.0, the second major update of the IV-PSNR software package for objective quality assessment in immersive video systems. Similarly to earlier versions, the software provides robust quality estimation adapted for the unique characteristics of immersive video, such as geometric inaccuracies, view-dependent illumination, and typical multiview reconstruction artifacts. The new version introduces three improvements: (1) a new structural-similarity-based immersive quality metric: IV-MS-SSIM; (2) a significant performance optimization of all structural-similarity-based metrics based on substituting the 11 × 11 Gaussian window by an 8 × 8 square window with partial overlapping; (3) multithreading optimization.

Metadata

Nr	Code metadata description	*Please fill in this column*
C1	Current code version	v8.0
C2	Permanent link to code/ repository used for this code version	https://github.com/jstankowski/ivpsnr
C3	Permanent link to reproducible capsule	https://github.com/jstankowski/ivpsnr/tree/main/example
C4	Legal code license	BSD-3-Clause
C5	Code versioning system used	git
C6	Software code languages, tools and services used	*C*++
C7	Compilation requirements, operating environments and dependencies	CMake 3.15 or newer, *C*++17 conformant compiler (e.g., GCC 10.0 or newer, clang 13.0 or newer, MSVC 19.15 or newer), external libraries: fmtlib, libspng, and miniz – automatically downloaded during CMake build process
C8	If available, link to developer documentation/ manual	https://github.com/jstankowski/ivpsnr#readme
C9	Support email for questions	jakub.stankowski@put.poznan.pl

1. Description of the software-update

The IV-PSNR software is designed for objective quality assessment of immersive video, where users freely navigate through a 3D scene watching images generated by a view rendering pipeline [1–3]. Such content exhibits specific distortions, including slight geometric shifts caused by reprojection and viewpoint-dependent illumination changes [4]. The software is optimized to handle these effects, providing objective scores that highly correlate with perceived subjective quality.

This paper describes IV-PSNR v8.0, which introduces 3 major changes: the new IV-MS-SSIM metric (Section 1.1), a significant performance optimization of all SSIM-based metrics due to using 8 × 8 blocks with a stride of 4 instead of an 11 × 11 Gaussian window (Section 1.2), and more effective parallelization on high core-count CPUs (Section 1.3). These changes significantly increased the performance and efficiency of the IV-PSNR software for both immersive and non-immersive video systems (Section 1.4).

1.1. An extended list of quality metrics

First versions of the IV-PSNR software [7] included the calculation of three PSNR-based objective quality metrics: basic PSNR (Peak Signal-to-Noise Ratio), IV-PSNR (PSNR for Immersive Video) [4], and

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WS-PSNR (Weighted-to-Spherically-uniform PSNR) [8]. Version 7.1 [9] introduced three state-of-the-art metrics based on structural similarity estimation: basic SSIM (Structural Similarity Index Measure) [10], IV-SSIM (SSIM for Immersive Video) [11], and MS-SSIM (Multi-Scale SSIM) [12].

Considering the superiority of MS-SSIM when compared to SSIM, the Authors of this paper took a natural next step, developing a metric adapted to immersive video based on multiscale SSIM: IV-MS-SSIM [13].

As presented in Fig. 1, the newly developed IV-MS-SSIM metric combines the advantages of multiscale structural similarity and IV-PSNR, clearly outperforming state-of-the-art metrics in immersive video applications (Fig. 1A). Moreover, it performs competitively in other scenarios (Fig. 1B), proving the high versatility of the metric and IV-PSNR v8.0 software itself.

1.2. Performance optimization for structural similarity metrics

In addition to a new metric, IV-PSNR v8.0 introduced a significant improvement in the computational efficiency of all structural-similarity-based metrics [13]. The computation of all SSIM, MS-SSIM, IV-SSIM, and IV-MS-SSIM metrics has been reworked to use 8 × 8 square blocks instead of the classical Gaussian 11 × 11 window. Using simple average instead of Gaussian filtering allowed for integer-based implementation, while a change of a block size resulted in a possibility of simple vectorization of SSIM-based metric calculations, utilizing efficient SIMD processing, including SSE, AVX2, and AVX512 extension sets. Moreover, instead of sweeping the window pixel-by-pixel, a stride equal to four (horizontal and vertical) has been introduced. It allowed for significant computational time and memory reduction while preserving correlation with subjective quality.

With the proposed change, all the SSIM-based metrics are computed significantly faster than in the previous version of the software. The results of SSIM, MS-SSIM, IV-SSIM, and IV-MS-SSIM are similar to the ones computed using classical, non-optimized implementation, but not exactly the same. However, the experiments [13] have proven that the correlation between computed metrics and mean opinion score is preserved (with negligibly higher correlation when using the optimized algorithm, c.f. Table 1).

It is worth noticing that the approach with 8 × 8 square blocks and 4-pixel stride is already used in several libraries/tools like FFMPEG or HDRTools [14]. If a user of the IV-PSNR software prefers to use a classical Gaussian 11 × 11 window without stride, all SSIM-related calculation settings can be changed at runtime by providing adequate commandline parameters (described in README.md)

1.3. Reduced multithreading overhead

The multithreading implementation (thread pool) has been completely overhauled to reduce locking overhead related to passing work items to worker threads (by ∼10 %). In addition, the work items are created in the form of small multi-row chunks and dynamically distributed across all computing resources. This leads to efficient workload distribution on both homogeneous and heterogeneous CPUs and an eightfold reduction of lock contention.

Table 1
Computational time reduction and correlation increase achieved using the proposed performance optimization for SSIM and IV-SSIM in two tested scenarios: immersive (IV) and non-immersive (TID) video.

	IV: SSIM	IV: IV-SSIM	TID: SSIM	TID: IV-SSIM
Time reduction	96.5 %	88.4 %	90.2 %	83.6 %
Corr. increase (PLCC/ KROCC/SROCC)	0.03 / 0.02 / 0.02	0.01 / 0.02 / 0.01	0.01 / 0.01 / 0.00	0.00 / 0.00 / 0.00

1.4. Usability

The IV-PSNR software was originally created for the purpose of developing the ISO/IEC 23090–12 MPEG immersive video (MIV) coding standard [21,22], where it has been included in the MIV common test conditions and widely used for immersive video coding research. Version 8.0 of the software (also distributed under the name QMIV [15]) is currently used for the evaluation of ongoing standardization activities related to Gaussian Splat Coding (GSC).

The addition of the IV-MS-SSIM metric expands the set of structural similarity metrics adapted to immersive content, enabling more accurate quality assessment in various types of immersive video and virtual reality systems. Moreover, due to algorithmic optimizations, the calculation of all SSIM-based metrics is significantly faster than in earlier versions.

Altogether, improvements introduced in version 8.0 significantly increase the efficiency and performance of the IV-PSNR software, making it a perfect solution not only for immersive video coding research but also for other image and video processing applications across diverse hardware and software platforms.

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CRediT authorship contribution statement

Jakub Stankowski: Conceptualization, Investigation, Software, Writing – original draft. **Adrian Dziembowski:** Conceptualization, Methodology, Writing – original draft.

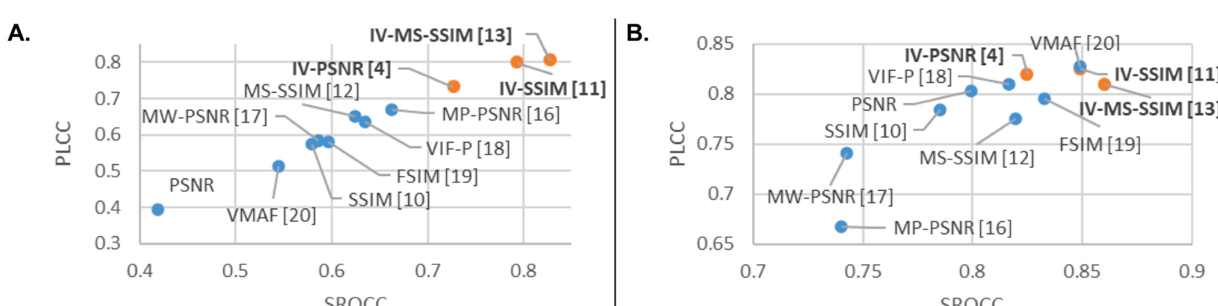

Fig. 1. Correlation between objective and subjective quality – PLCC and SROCC [5] values for considered metrics in two applications: A: immersive video, B: non-immersive video (TID2013 database [6]). State-of-the-art metrics used in comparison: PSNR, IV-PSNR [4], SSIM [10], IV-SSIM [11], MS-SSIM [12], MP-PSNR [16], MW-PSNR [17], VIF-P [18], FSIM [19], VMAF [20], and newly added IV-MS-SSIM [13]. Results from [9] and [13].

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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