Selective Adaptive Video Watermarking Technique Against Compression and Frame Deletion Attacks*

Chaewan Hong†, Seung-ha Jee and Il-Gu Lee
Sungshin Women's University, Seoul, South Korea
20220623@sungshin.ac.kr, {shjee2001, iglee19}@gmail.com

Abstract

The increasing availability of digital content has made watermarking technology more important for preventing illegal copying and tampering. This study proposes an adaptive watermarking technique that selects between a conventional single insertion method and a proposed frame-splitting insertion method based on compression strength. This addresses the issue of degraded watermark recovery performance in compressed and frame loss environments. Experimental results show that the average BER of the adaptive technique decreased by 42% compared to the conventional model and by 32% compared to the proposed model across various attack environments.

Keywords : Adaptive, Video Watermarking, Split, Compression, Frame deletion

1 Introduction

The growing amount of digital content has made digital watermarking technology increasingly important for protecting copyright and preventing data tampering. However, conventional video watermarking techniques directly modify the compressed bitstream, resulting in low compatibility due to structural differences between compression standards, as well as limitations such as cumulative errors during inter-frame prediction processes [1]. Furthermore, using a single insertion structure has the limitation that its recovery performance is inconsistent when the attack environment changes. Therefore, this study proposes a watermarking technique that adaptively selects between two methods based on compression strength.

2 Adaptive Video Watermarking Scheme

Figure 1(a) shows the operation of the adaptive technique, and (b) shows the embedding structure of the proposed model. This technique detects the Quantization Parameter(QP) value during encoding to select the optimal watermarking method. When the QP value is 0, during re-encoding, the conventional redundancy insertion method is used[2]. When the QP value is greater than 0, a frame-based split insertion method is employed to enhance robustness against distortion in compressed environments.

* Proceedings of the 9th International Conference on Mobile Internet Security (MobiSec'25), Article No. P-65, Decem ber 16-18, 2025, Sapporo, Japan.
† Corresponding author

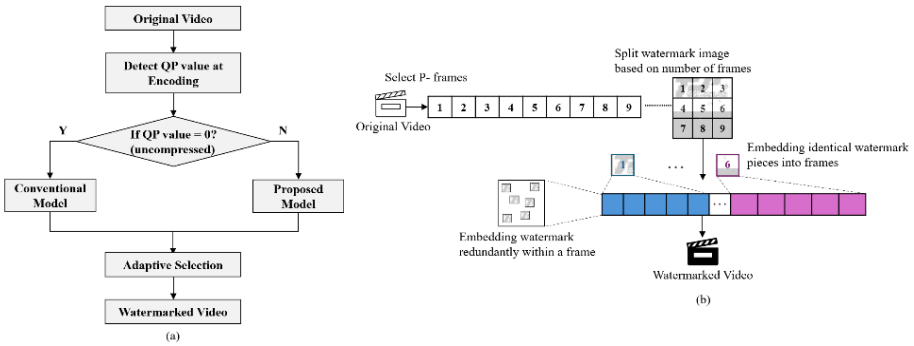

Figure 1. (a) Flowchart of Adaptive Video Watermarking Scheme and (b) Split embedding process

Conventional techniques involve repeatedly inserting the same watermark into all frames, which enables the watermark to be restored from the remaining frames even if some are lost. However, distortions occurring during compression accumulate across the entire frame with this repeated insertion method, reducing robustness. In contrast, the proposed segmented insertion technique divides the watermark into segments, which are then inserted selectively into low-motion blocks of P-frames. This mitigates the cumulative distortion caused by compression loss and enhances restoration stability.

3 Evaluation results Analysis and Conclusion

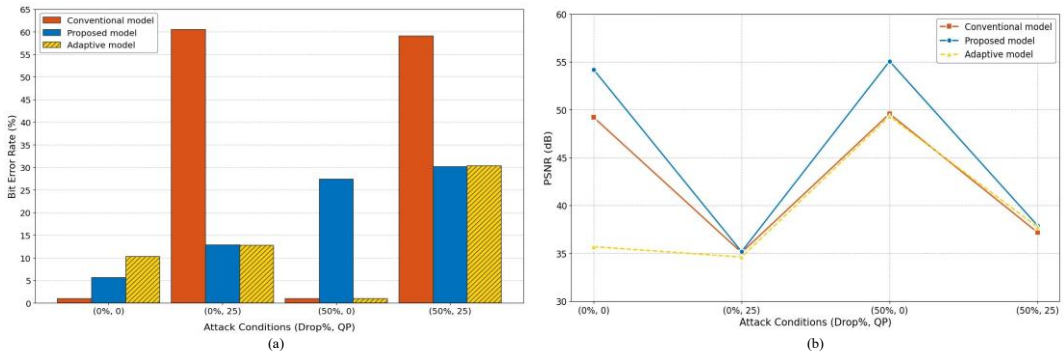

Figure 2. Evaluation result of (a) BER and (b) PSNR under compression and frame drop attacks

Figure 2 shows the (a) Bit Error Rate(BER) and (b) PSNR results of the conventional model, the proposed model, and the adaptive technique under varying compression strength and frame deletion rate attack conditions. When only compression attacks are present, the proposed model effectively mitigates distortion accumulation caused by compression loss, prompting the adaptive technique to select the proposed model. When only frame deletion attacks occur, the adaptive technique selects the conventional model that can restore the watermark with just one frame. However, when both attacks occur simultaneously, the selected model changes depending on the compression strength. At low compression, the iterative insertion method of the conventional model enables complete restoration of the watermark even after frame loss, so the adaptive technique selects the conventional model. As compression strength increases, however, the loss-resilient proposed model demonstrates more stable restoration performance, leading the adaptive technique to select the proposed model. Consequently, under attack conditions, the adaptive technique achieves a 42% reduction in BER compared to the conventional model and a 32% reduction compared to the proposed model. This result overcomes the limitations of a single watermarking scheme and demonstrates the effectiveness of the adaptive structure that switches insertion strategies based on frame loss during encoding and compression strength. Furthermore, all models achieved PSNR values

above 30 dB, confirming that the proposed adaptive technique has an insignificant effect on image quality, even during watermark insertion. This study proposes an adaptive video watermarking method that applies context-optimized strategies to minimize performance deviation in watermark recovery due to compression strength. Future research will extend this approach to the audio domain, developing a robust watermarking technique capable of operating in environments with voice modulation.

References

[1] Jakub Stankowski, Marek Doma ski, and Tomasz Grajek, “Fast and Energy-Efficient Watermarking of HEVC-Co mpressed Video Bitstreams,” Proceedings of the 2022 30th European Signal Processing Conference (EUSIPCO), A ug. 2022

[2] Ahmed Al-Gindy, Aya Al-Chikh Omar, and Omar Mashal, “A new watermarking scheme for digital videos using DCT,” Open Computer Science, vol. 12, no. 1, Jul. 2022