

Reviewer's opinion
on Ph.D. dissertation authored by
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entitled:

Analysis, Extensions, and Optimizations of High-Efficiency Video Compression Techniques

1. Problem and its impact

Importance. This work is important for applications such as video streaming, broadcasting, video storage, 3D television, free-viewpoint television, immersive media, and digital content protection, as it improves video compression efficiency in 2D and multi-view video, reduces computational complexity, and enables watermarking for copyright protection and content authentication.

Video compression depends on a complex interaction between prediction, transform, quantization, entropy coding, and decisions made by the encoder. The candidate addresses problems of clear scientific significance and practical relevance. The dissertation investigates how knowledge of coding statistics, prediction decisions, and scene geometry can be used to improve compression or extend the capabilities of existing standards without requiring a completely new coding architecture. The dissertation concentrates on AVC and HEVC but the concepts it explores are applicable to generic hybrid coding systems, including VVC and Enhanced Compression Model (ECM).

Scientific contributions. The scientific contributions brought by the candidate are important, as demonstrated by the numerous scientific publications, comprising a journal paper in a special issue in the top-level *IEEE Transactions on Image Processing* journal, international conferences, including a best paper award at IWSSIP, and contributions to MPEG.

Practical relevance. Improvements in compression efficiency reduce transmission bandwidth and storage requirements, while reductions in encoder complexity lower processing time and energy consumption. Video coding standards are used in numerous applications in various domains. The proposed contributions are totally relevant and significant from practical point of view because they address optimizations of existing video coding standards, and they improve performance / computational complexity while maintaining standard compliance.

2. Contribution

Thesis structure and contributions: The work is organized around three stated research theses: (i) exploiting statistical properties of encoded video to reduce encoder complexity while maintaining coding efficiency; (ii) using scene geometry to improve coding of motion and disparity information for multiview video; and (iii) embedding robust watermarks with substantially lower computational effort than pixel-domain approaches.

Chapter 1 provides a detailed experimental analysis of HEVC bitstream statistics, including frame partitioning, the bitrate contributions of different frame types, syntax-element distributions, and CABAC probability estimation. The findings are used to motivate and develop encoder-control strategies, including mode selection assisted by precomputed statistics leading to substantial encoding

time reductions at minimal BD-R penalties. This connection between empirical analysis and practical optimization is one of the strong aspects of the dissertation.

Chapter 2 develops two encoder-side improvements. The proposed exact-cost approach to Rate-Distortion Optimized Quantization (RDOQ) reports approximately a 1% improvement in compression efficiency relative to the reference implementation. The motion-estimation work investigates the influence of starting-point selection, search-range adaptation, and distortion metrics on computational complexity and coding performance.

Chapter 3 contributes to multiview video coding, including motion- and disparity-vector prediction leading to 2% improvement in coding efficiency, depth-map distortion estimation, and FTV systems with arbitrary camera locations. One notes the contribution of the candidate to the successful 3D video codec based on HEVC improving coding efficiency by 58% and 70% for 2 views and 3 views respectively. The chapter reflects the ability of the candidate to carry out teamwork and efficiently perform in a large team.

Chapter 4 develops a compressed-domain watermarking approach for AVC and HEVC. The AVC contribution comprises watermarking based on scaling matrices and transform coefficients watermark embedding. The HEVC contribution comprises transform-unit selection for watermark embedding, drift avoidance, and interactions with coding tools such as Sign Data Hiding. The experiments illustrate a meaningful trade-off between robustness, visual quality, and bitrate overhead.

Overall, the thesis's strength lies in the combination of algorithm design, experimental evaluation, and practical relevance to video coding systems. Regarding originality, the dissertation clearly identifies which results are the candidate's own and which involved collaboration. It reports substantial personal contributions to several publications, while explicitly acknowledging smaller contributions to other (detailed figures in section 0.2). This transparency is valuable.

Publications. The dissertation lists 16 publications, including journal articles, conference papers, and a book/proceedings chapter of which the candidate is first author for 12 of them. The candidate is author of 4 journal papers of which 2 are IEEE journals. The candidate has also obtained an award for one of his publications (A5) at an international conference (IWSSIP 2013). I remark the authorship of a well cited paper (A13) in a special issue in the highly prestigious *IEEE Trans. on Image Processing* journal.

3. Correctness

I consider the dissertation's technical approach credible and its results supported by experimental evidence. The candidate makes use of established video-coding frameworks and reference implementations; the experimental setup adheres to established protocols in the video compression literature, ensuring scientific rigor.

Overall, the thesis is characterized by sound reasoning, a rigorous methodology, appropriate argumentation of the proposed ideas, appropriate analysis of the experimental results, benchmarking against state of the art reference methods, and well-substantiated conclusions regarding the effects of the proposed methods on compression efficiency and encoding time.

4. Knowledge of the candidate

The dissertation provides substantial evidence that the candidate has broad knowledge of Information and Communication Technology, particularly in video compression, multimedia signal processing, encoder implementation, and digital content protection.

The introductory chapter is the clearest tutorial-style component. It covers the evolution of hybrid video coding standards, including AVC, HEVC, and VVC. Chapter 1 extends that background through a detailed treatment of HEVC statistics. Chapter 2 demonstrates specialized knowledge of rate-distortion

optimization, quantization, motion estimation, search strategies, distortion metrics, and processor-level optimization. Chapter 3 demonstrates knowledge of multiview coding, 3D video representation, depth maps, motion- and disparity-vector prediction, and free-viewpoint television. Chapter 4 covers compressed-domain watermarking, demonstrating the candidate's ability to address multimedia security and content protection problems.

The candidate demonstrates in-depth knowledge with the relevant standards, the scientific literature, experimental methodology, and practical implementation challenges. The reference list is comprehensive and comprises a rich video coding literature. The dissertation cites the candidate's publications and details collaborative work.

Overall, the thesis demonstrates in-depth knowledge and the ability of the candidate to analyse, experiment, innovate, improve, and assess trade-offs in video compression.

5. Other remarks¹

A detailed set of technical questions and remarks will be provided to the candidate and promoter prior to the PhD defence.

6. Conclusion

Taking into account what I have presented above and the requirements imposed by Article 187 of *the Act on Higher Education and Science of the Polish Parliament* (Dz. U. 2018 poz. 1668 with amendments)², my evaluation of the dissertation according to the three basic criteria is the following:

A. Does the dissertation present an original solution to a scientific problem? (the selected option is marked with X)

☒	☐	☐	☐	☐
<i>Definitely YES</i>	<i>Rather yes</i>	<i>Hard to say</i>	<i>Rather no</i>	<i>Definitely NO</i>

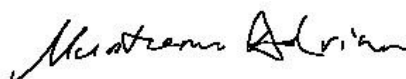
B. After reading the dissertation, would you agree that the candidate has general theoretical knowledge and understanding of the discipline of **Information and Communication Technology**, and particularly the area of?

☒	☐	☐	☐	☐
<i>Definitely YES</i>	<i>Rather yes</i>	<i>Hard to say</i>	<i>Rather no</i>	<i>Definitely NO</i>

C. Does the dissertation support the claim that the candidate is able to conduct scientific work?

☒	☐	☐	☐	☐
<i>Definitely YES</i>	<i>Rather yes</i>	<i>Hard to say</i>	<i>Rather no</i>	<i>Definitely NO</i>

Moreover, taking into account the substantial volume of work and quality of scientific contributions, I **recommend to distinguish** the dissertation for its quality³.



¹ Optional

² http://www.nauka.gov.pl/g2/oryginal/2013_05/b26ba540a5785d48bee41aec63403b2c.pdf

³ Obviously, this sentence is optional.