The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Raees Kizhakkumkara Muhamad**

The public defense will take place on **Wednesday 5th February 2025 at 4pm** in room **I.0.01** (Building I, VUB Main Campus)

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COMPRESSION STRATEGIES FOR DIGITAL HOLOGRAPHY

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Abstract of the PhD research

Holographic techniques sample a 2D interference pattern produced by coherent light waves reflected or transmitted from the different objects in the 3D scene. As a display technology, it provides all necessary visual cues for perceiving the scene by the brain without causing mismatches between accommodation and vergence of the eyes. Non-destructive imaging with high resolution for biomedical and industrial inspection also utilizes holographic principles. Holographic microscopes are realizable with optically simpler setups than regular microscopy, opening new pathways for computational microscopy. Utilizing more complex arrangements, such as holographic tomography, allows for reconstructing the 3D refractive index profile of transmissive objects, resolving even sub-cellular structures with visible light. It represents the culmination of humanity's effort to record and represent light information.

However, sampling interference patterns for high-end displays or high-resolution microscopy result in an extensive digital footprint. Historically, for many multimedia use cases, the data transmission bottleneck dictated the fidelity of the consumed content, and one can expect holography to be no different. Compression algorithms can help mitigate the data load, trading off more computation for an effective increase in transmission capacity. The algorithms must be tailored for holograms used in practice and exhibit a computational complexity appropriate for the use case, particularly on the decoder side. This thesis presents compression strategies for effectively tackling such use cases for holography.

The performance of conventional image compression tools on metrological hologram content is first studied. We provide a novel analysis of compression artifacts on the retrieved metrological data obtained for digital holographic microscopy and tomography. First-generation holographic displays are poised to use binary representation due to difficulties in modulating pixels at the sizes required by holography. Context-based compression is adequate for lossless and near-lossless compression of such data. Here, one extracts from a pixel the redundant information from previously decoded neighbouring pixels using a generalized Markovian model. Another context-based framework utilizing linear (autoregressive) models is used to design a highly scalable lossless compression scheme for non-binary holographic data. For broadcast scenarios, it is desirable to have a compression system that can support view-selective decoding to minimize the transmission of unutilized information. For this purpose, we propose a short-time Fourier transform (STFT) based codec, which slices the hologram into independently decoded, spatio-angular chunks. Given a target mean-squared error, the optimization techniques efficiently round down the signal in the STFT domain by application of adaptive quantizers. All these compression schemes are applicable for a single frame of hologram data and feature lightweight decoding architectures while surpassing compression performances achieved by any existing solution on most tested holograms. To compress holographic videos with arbitrary motion, we utilize a novel motion compensation algorithm that can predict rotational motion in conjunction with the above-mentioned STFT framework. The Markovian and STFT frameworks discussed in this work have been adopted as part of the first international hologram compression standard, JPEG Pleno — Part 5: Holography (ISO/IEC 21794-5).