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Pattern-Based De-Correlation for Visual-Lossless Video Compression for Wireless Display Applications

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Abstract—The core of many video coding standards is formed by the Discrete Cosine Transform (DCT) for de-correlating spatial video data. When applied to symmetrical spatial data or patterns as found in graphical data, the DCT results in zero-valued sub-bands at predefined positions in the transform domain. The DCT de-correlation is further improved when scan paths are defined that omit the aforementioned zero-valued sub-bands. When deploying these predetermined scan paths on regular video, Human Visual System (HVS) based quantization is applied to force similar sub-bands to zero, such that the remaining energy matches a particular scan path. As a result, visual-lossless compression of video and graphics up to a factor four (2-4) with a PSNR of 40-45 dB is achieved, making this technique suitable for wireless display applications.

I. INTRODUCTION

Transmission of audiovisual information via a wireless link may suffer from the situation that the error correction of the wireless link fails to correct corrupted data. Instead of directly loosing connection and data, investigations of the Wireless Gigabit Alliance (WGA) aim at re-establishing the wireless link while compressing the payload and using the created data space for additional error-correction parities. For this approach, a compression scheme is required, which is visually lossless at modest compression ratio (factor 3 to 4) for both graphical and natural-video data, thereby avoiding noticeable image quality deterioration. Other crucial aspects are cost and latency, while latency is especially important for gaming due to the optical feedback. Visually lossless video compression can be achieved when applying H.264 intraframe compression to graphics and natural video for compression ratios of 3 to 4. Spatial prediction, which can be regarded as a de-correlation step prior to the DCT de-correlation, is a key aspect of H.264 intraframe compression, resulting in an adequate compression of graphics and natural data. Although spatial prediction modes positively contribute to the coding efficiency, they negatively influence implementation cost due to the presence of a local decoder and an additional line-memory at the encoder.

This paper presents a low-cost pattern-based de-correlation method suitable for graphical data to improve a DCT-based encoding scheme, which also works for the coding of natural video, when forcing certain sub-bands to zero, based on HVS-based quantization. This compression scheme is intended for usage in wireless consumer display for improving the robustness in case of errors.

II. SPATIAL SYMMETRIES AND PATTERNS

Transforming spatial data using a 2D-DCT transform, results in a matrix of equal dimensions containing the coefficient amplitudes of associated sub-bands. The number of zero-valued sub-bands differs, all depending on the spatial content, where we have observed that particular sub-bands are always zero-valued for a particular spatial pattern, see Fig. 1. Video compression basically consists of three stages: de-correlation, quantization and entropy coding. The performance of the de-correlation and entropy-coding stages influence the amount of quantization required to achieve a certain compression ratio. Visually lossless video compression requires careful de-correlation, especially for graphical data, in order to minimize the amount of quantization. The pattern phenomenon as depicted in Fig. 1 enables further de-correlation by explicitly discarding all the zero-valued coefficients. Note that one or more coefficients located at the x-positions in the DCT matrix may be zero, see Fig. 1, all depending on the intensity of the spatial video. These zero-values have to be taken into account by the entropy-coding stage. The number of supported symmetries or patterns has a direct influence on the implementation costs and therefore has to be minimized. As a result, we have created a limited set of symmetries and patterns as in Fig. 2, based on the frequency of occurrence in graphical data. The spatial content of Fig. 2(g) does not result in zero-valued columns or rows, but in symmetry, which also enables sub-band reduction. Another form of Fig. 2(g) occurs when the symmetry takes place along the anti-diagonal axis, which again reduces the number of sub-bands. Natural video does not follow the patterns as depicted in Fig. 2 and requires a dedicated quantization step resulting in one of the supported patterns.
III. CODING SCHEME AND EXPERIMENTAL RESULTS

The symmetries and patterns as described in Section II, are deployed to construct an intraframe codec, as depicted in Fig. 3. This coding scheme deploys a 4x4 DCT and quantization, as described in H.264 [1], and HVS-based quantization to remove particular sub-bands [2], forcing a DCT block to fit with one of the supported patterns. The position of symmetry-based quantization can be prior to or after regular quantization. The position of the HVS-based additional quantization in the coding scheme has a strong influence on its effectiveness. When applying symmetry-based quantization prior to regular quantization, see Fig. 3 (b), the coding benefit for natural video is smaller than for Fig. 3(a), see Table 1. When applying symmetry-based quantization after quantization, see Fig. 3(a), the coding benefit is significant, see Table 2. The symmetry modes in Table 1 and 2, correspond to the patterns as depicted in Fig. 2, and is extended with a non-symmetry (Ns) mode. The former corresponds to situations where there is only a DC-value, from which the entropy-coding stage can benefit. This is caused by the fact that the DCT energy is deterministic per symmetry mode. A no-symmetry mode is required for the situation that symmetry quantization fails to deliver a suitable pattern. Table 1 indicates the application rate of symmetries on original video data. It becomes apparent that only a quarter of all DCT blocks are processed based on one of the symmetries. For the picture browse, a browser program showing thumbnails, already 74 % is symmetry-based coded. When quantizing the data, the amount of DCT blocks that are non-symmetry based and coded accordingly, is reduced to 27 % for the video data and 20 % for the browse picture. From Table 1 and 2 it becomes evident that when exploring patterns, the coding efficiency is increased, positively influencing the amount of quantization required to achieve the intended compression ratio (lower regular Q value). This benefit is partly compensated by the fact that some regions are quantized towards a zero-valued sub-bands, creating some additional distortion. Figure 4 indicates the performance of this approach for a set of pictures. Especially graphics related content benefits from the pattern-based coding approach. This is essential due to the high sensitivity for distortion in this type of video material. This is confirmed by the fact that for graphics data such as the picture ruler, no additional quantization is required, as indicated in Fig. 4, for Q=4. Also, a mixture of video and graphics data, as is the case for the browse picture, benefits from this coding scheme, resulting in the highest picture quality at modes quantization. Moreover, regular video still has a high PSNR, when compressed at a factor 3 to 4.

IV. CONCLUSIONS

For pictures with a reasonable amount of graphics, we can deploy symmetry-based quantization, due to the frequent occurrence of patterns with zero-valued sub-bands. Furthermore, this symmetry-based quantization can be applied on top of regular quantization as in H.264 coding, such that the coding of natural video also benefits from this approach, at the expense of a somewhat lower PSNR. This coding scheme gives 40-45 dB PSNR at compression ratios 2-4.

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