Entropy-Constrained Linear Vector Prediction for Motion-Compensated Video Coding

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Abstract — **Theoretical and experimental results for motion-compensated linear prediction of video signals are presented. The rate distortion theory of motion-compensated prediction is extended to linear predictive models. For practical implementations, linear vector predictors are employed. The rate of the motion data is controlled by minimizing a Lagrangian cost function where rate is weighted against distortion using a Lagrange multiplier. An adaptive algorithm for optimally selecting the number of input signals to the linear vector predictor is given.**

I. Theoretical Analysis

Following the framework for the rate distortion analysis of motion-compensated prediction in [1], we derive a closed form expression, where the power spectrum of the prediction error is related to the displacement pdfs of an arbitrary number of scalar input signals to the linear predictor. Previous work of Girod on the subject can be found in [2].

Let $s[x, y]$ be a scalar two-dimensional signal sampled on an orthogonal grid. We model motion-compensated prediction as the prediction of the signal s by modified versions of itself $\hat{s}_i$. The $\hat{s}_i$ are modified from s in that they are shifted by arbitrary displacements and corrupted by additive noise z_i. Motion-compensation is assumed to be the alignment of the $\hat{s}_i$ to s up to a certain accuracy producing the motion-compensated signals c_i. The alignment data, i.e., the displacement vector field, can never be completely accurate since it has to be transmitted as side information to the video decoder. Fig. 1 shows the prediction gain as a function of the

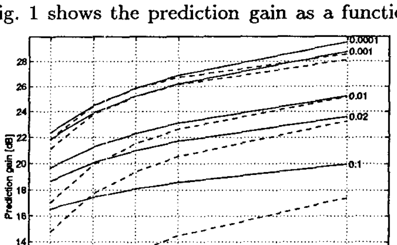

Fig. 1: Comparison of prediction gain in [dB] when using the Wiener filter (solid) against the case of averaging the N motion-compensated signals $\hat{s}_i$ (dashed).

number of input signals or hypotheses when using a Wiener filter for superposition of the $\hat{s}_i$ as solid line. The case when the N hypotheses are simply averaged is depicted as dashed line. The curves are parameterized for various residual noise levels σ_z^2 of z_i. The relative gains when increasing the number of hypotheses depend on σ_z^2 and the superposition method.

II. Experimental Results

In our experiments, the superposition coefficients are fixed to the value $1/N$. We conduct a search to find the optimum input vectors, which are mutually dependent. An iterative algorithm avoids searching the complete space by successively improving n optimal conditional solutions [3]. Convergence to a local optimum is guaranteed, because the algorithm prohibits an increase of the error measure. The criterion for the search is the minimization of a Lagrangian cost function where distortion is weighted against rate using a Lagrange multiplier similar to entropy-constrained vector quantization [4]. Also the number of effective hypotheses N per block is tested using the Lagrangian cost function resulting in a varying number of hypotheses N that can be used for each block.

Figure 2 shows three cases: (1) half-pel accurate prediction of 16×16 blocks using blocks that are addressed in last frame allowing only $N = 1$ hypothesis, (2) as case 1 but the 10 last frames are used, (3) as case 2, but prediction using the superposition of $N = 1$ up to $N = 4$ blocks. Extending motion compensation from 1 to 10 frames provides about 1 dB PSNR gain at about 4 kbit/s increased bit-rate while 2.3 dB can be gained using linear vector prediction at 6 kbit/s increased bit-rate.

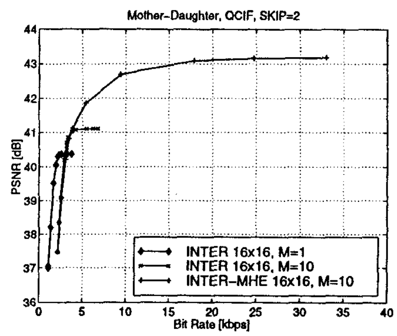

Fig. 2: PSNR vs. bit-rate of the for the sequence *Mother-Daughter* (QCIF, 10 fps, 10s), and 16×16 blocks.

For more details please refer to the extended version of the paper that is available at: http://www-nt.e-technik.uni-erlangen.de/~wiegand/isit98fp.pdf or to [3].

References

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