Inter Prediction using Estimation and Explicit Coding of Affine Parameters

Cordula Heithausen, Jens-Rainer Ohm

Lehrstuhl und Institut für Nachrichtentechnik
RWTH AACHEN UNIVERSITY

Outline

- Introduction and Motivation
- Estimation of Affine Parameters
- Block-to-Block Translational Shift Compensation - BBTSC
- Higher Order Distance Scaling - HODS
- Quantization and Coding of Affine Parameters
- Evaluation

Introduction: Motivation for Higher Order Motion Compensation

- Conventional motion compensation (HEVC-compliant)[2]
  - Estimation of motion vector via *block-matching*
  - Transmission of block-wise **translational** motion vector and residual
- **But what about non-translational motion?**
  - Higher order motion **approximated** by smaller units of translational motion
    - **High data rate costs** (due to block partitioning and estimation error)

- **Higher Order Motion Compensation (HOMC)**
  - Block-wise option of additional parameters describing non-transl. motion
  - Implementation in HM14.0-KTA1.0[3]
  - Adaptation: higher precision sub-sample interpolation and quantization

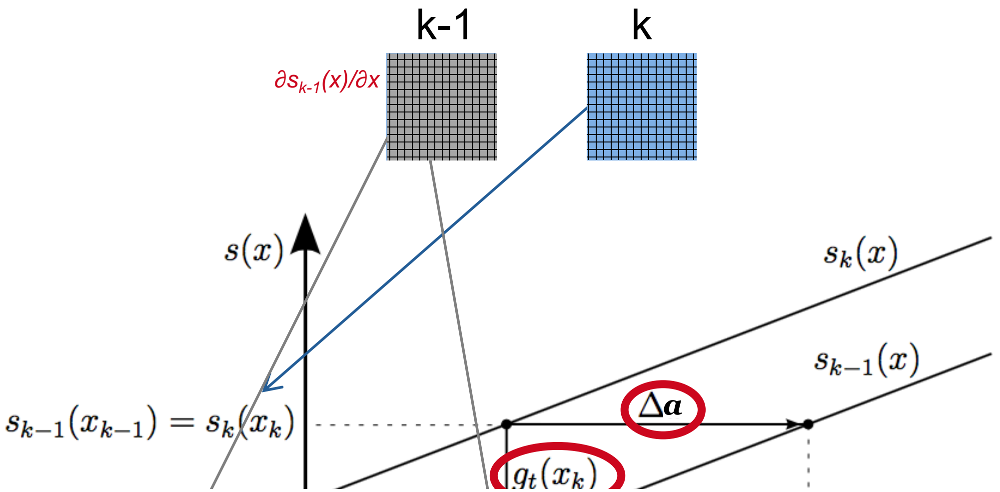
  - **Differences to affine mode in JEM**
    - **Estimation and explicit coding of affine parameters**
    - **Usage of both simplified and full affine motion model**
    - **Temporal affine motion prediction**

Higher Order Motion Parameter Estimation

- Iterative motion estimation method based on temporal and spatial local gradients[1]

$$\underbrace{\begin{pmatrix} g_t(\boldsymbol{x}_0) \\ g_t(\boldsymbol{x}_1) \\ \vdots \\ g_t(\boldsymbol{x}_{N-1}) \end{pmatrix}}_{\boldsymbol{G}_t} = \underbrace{\begin{pmatrix} \boldsymbol{h}^{\mathrm{T}}(\boldsymbol{x}_0) \\ \boldsymbol{h}^{\mathrm{T}}(\boldsymbol{x}_1) \\ \vdots \\ \boldsymbol{h}^{\mathrm{T}}(\boldsymbol{x}_{N-1}) \end{pmatrix}}_{\boldsymbol{H}} \cdot \underbrace{\begin{pmatrix} a_0 \\ a_1 \\ \vdots \\ a_{P-1} \end{pmatrix}}_{\Delta \boldsymbol{a}}$$

$$\Longrightarrow \Delta \boldsymbol{a} = \boldsymbol{H}^{+} \cdot \boldsymbol{G}_t$$



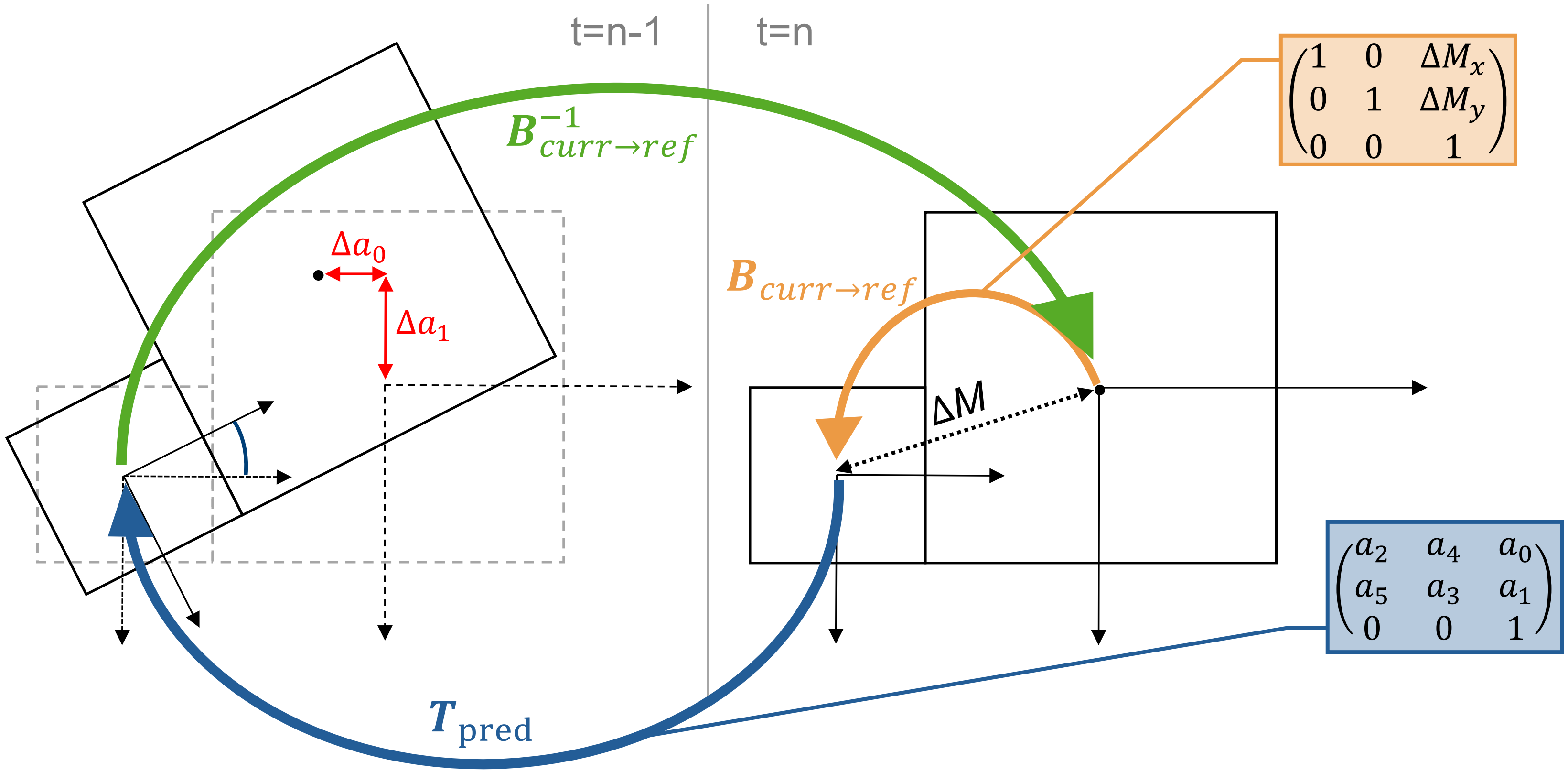
$\boldsymbol{h}^{\mathrm{T}}(\boldsymbol{x}_n)$ derived from transformation rules of individual motion models[4]:

$$\boldsymbol{h}^{\mathrm{T}}{}_{\mathrm{fullAff}} = \left(g_x, g_y, g_x x_k, g_y y_k, g_x y_k, g_y x_k\right)$$

$$\boldsymbol{h}^{\mathrm{T}}{}_{\mathrm{simpAff}} = \left(g_x, g_y, g_x x_k + g_y y_k, g_x y_k - g_y x_k\right)$$

[1] M. Narroschke and R. Swoboda, *Extending HEVC by an affine motion model*, in PCS, 2013.
[4] Cordula Heithausen and Jan Hendrik Vorwerk, *Motion Compensation with Higher Order Motion Models for HEVC*, in ICASSP, 2015.

BBTSC – Block-to-Block Translational Shift Compensation[5]

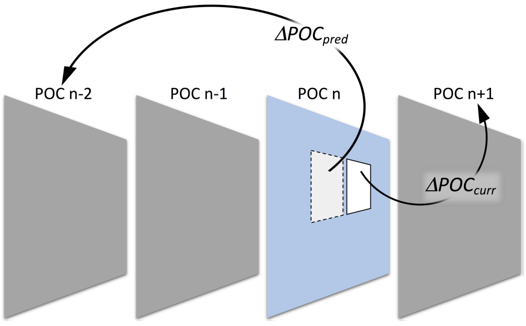


$$\hat{\boldsymbol{T}}_{\text{curr}} = \boldsymbol{B}^{-1}_{\text{curr}\to\text{ref}} \cdot \boldsymbol{T}_{\text{pred}} \cdot \boldsymbol{B}_{\text{curr}\to\text{ref}} = \begin{pmatrix} a_2 & a_4 & a_0 + \boxed{\Delta M_x(a_2 - 1) + \Delta M_y a_4} \\ a_5 & a_3 & a_1 + \boxed{\Delta M_x a_5 + \Delta M_y(a_3 - 1)} \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} \boldsymbol{\Delta a_0} \\ \boldsymbol{\Delta a_1} \end{pmatrix}$$

[5] C. Heithausen et al., *Improved Higher Order Motion Compensation in HEVC with Block-to-Block Translational Shift Compensation*, in ICIP, 2016.

HODS – Higher Order Distance Scaling[6]

$$\begin{pmatrix} a_2 & a_4 & a_0 \\ a_5 & a_3 & a_1 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} \Rightarrow \begin{pmatrix} a_2 & a_4 \\ a_5 & a_3 \end{pmatrix} \cdot \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} a_0 \\ a_1 \end{pmatrix} = \boldsymbol{A}\vec{x} + \vec{b}$$



$D = -0.5$

1. Determination of distance scaling factor $D = \frac{\Delta POC_{curr}}{\Delta POC_{pred}}$.
2. Decomposition of non-translational matrix $\boldsymbol{A} = \boldsymbol{A}_{rot} \cdot \boldsymbol{A}_{shear} \cdot \boldsymbol{A}_{scale}$ into higher order motion components φ, s_x, s_y, k.
3. Distance scaling of φ, s_x, s_y and k by distance scaling factor D, resulting in $\tilde{\varphi}, \tilde{s}_x, \tilde{s}_y$ and $\tilde{k}$.
4. Re-composition of distance-scaled matrix $\widetilde{\boldsymbol{A}} = \begin{pmatrix} \tilde{a}_2 & \tilde{a}_4 \\ \tilde{a}_5 & \tilde{a}_3 \end{pmatrix}$.

$$\tilde{\varphi} = D \cdot \varphi$$
$$\tilde{k} = D \cdot k$$
$$\tilde{s}_x = s_x^D$$
$$\tilde{s}_y = s_y^D$$

[6] C. Heithausen, M. Bläser, and M. Wien, *Distance Scaling of Higher Order Motion Parameters in an Extension of HEVC*, in PCS, 2016.

Quantization and Coding of Affine Parameters[4]

- Affine parameters represented in block-wise coordinate system

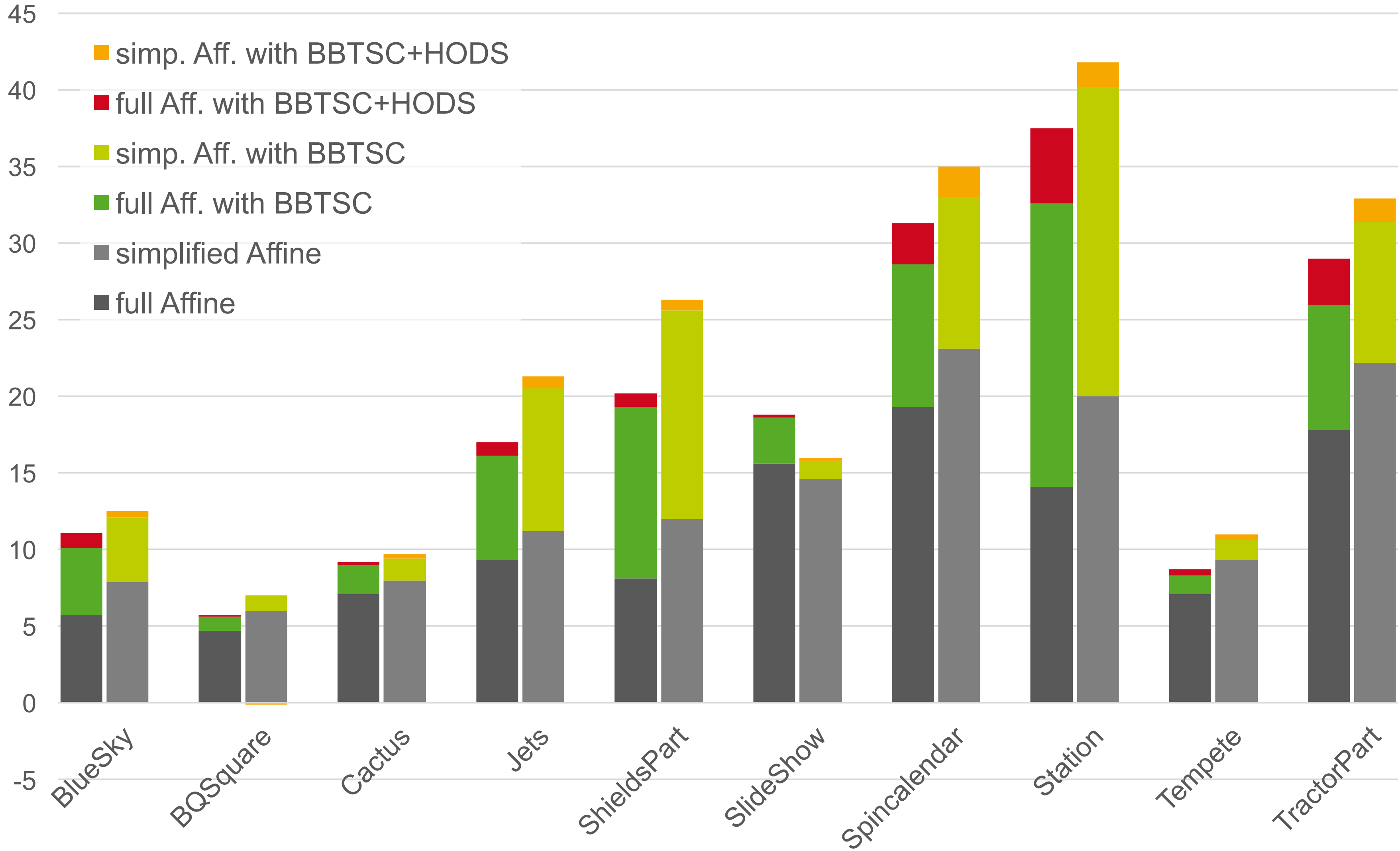
- Fine uniform quantization with quantization factor q>4, here q_{aff}=256

- Block-wise flag indicating if affine motion model is used
  - coded (if true) using different context depending on whether or not neighboured PU employs affine motion model as well

- Additional motion parameters (two or four, respectively)
  - if flag set *true*: signaled and coded similar to translational parameters
  - if flag set *false*: aff. Parameters set to identity matrix and not coded or transmitted

[4] Cordula Heithausen and Jan Hendrik Vorwerk, *Motion Compensation with Higher Order Motion Models for HEVC*, in ICASSP, Brisbane, Australia, April 2015, IEEE.

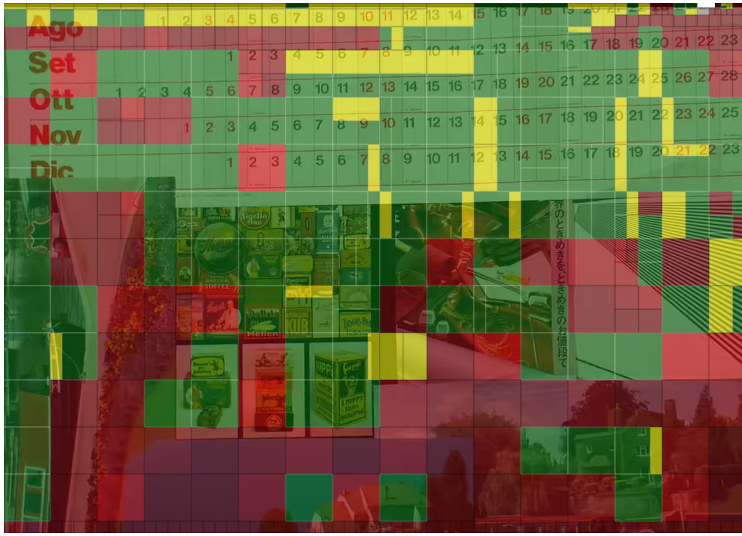
Rate Reduction of HOMC with BBTSC and HODS over KTA1.0 [%]

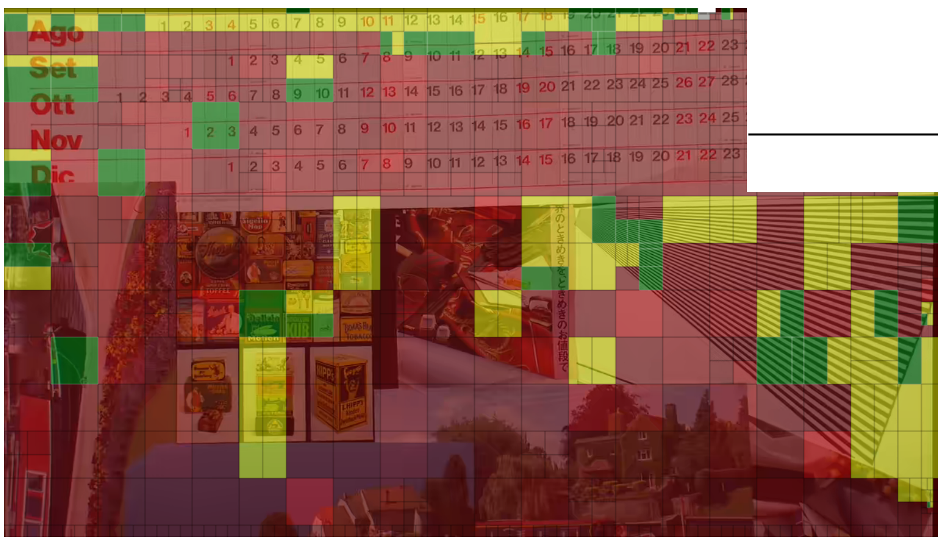


Rate Reduction for different modes: low delay P/B and random access

Sequence	LDP		LDB		RA	
	Aff.	Z&R	Aff.	Z&R	Aff.	Z&R
BlueSky	11.1	12.5	6.9	8.4	5.0	5.0
BQSquare	5.7	6.9	2.7	3.2	0.5	0.7
Cactus	9.2	9.7	8.4	9.0	6.9	7.7
Jets	17.0	21.3	14.8	19.2	5.0	5.7
ShieldsPart	21.2	26.3	13.7	19.7	9.2	11.8
SlideShow	18.8	16.0	18.1	15.6	10.9	10.7
Spincalendar	31.3	35.0	26.6	30.5	7.6	8.6
Station	37.5	41.8	30.5	37.2	17.1	22.0
Tempete	8.7	10.7	8.9	11.0	2.0	2.4
TractorPart	29.0	32.9	25.3	30.3	18.4	21.5
∅	**19.0**	**21.3**	**15.6**	**18.4**	**8.3**	**9.6**

Evaluation – *Prediction mode occurrences with/without BBTSC*

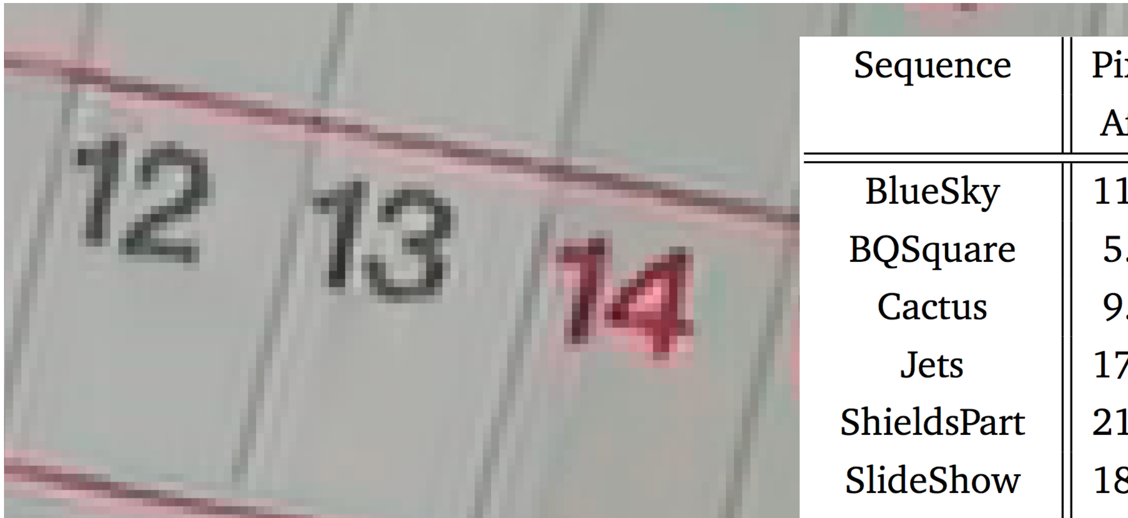


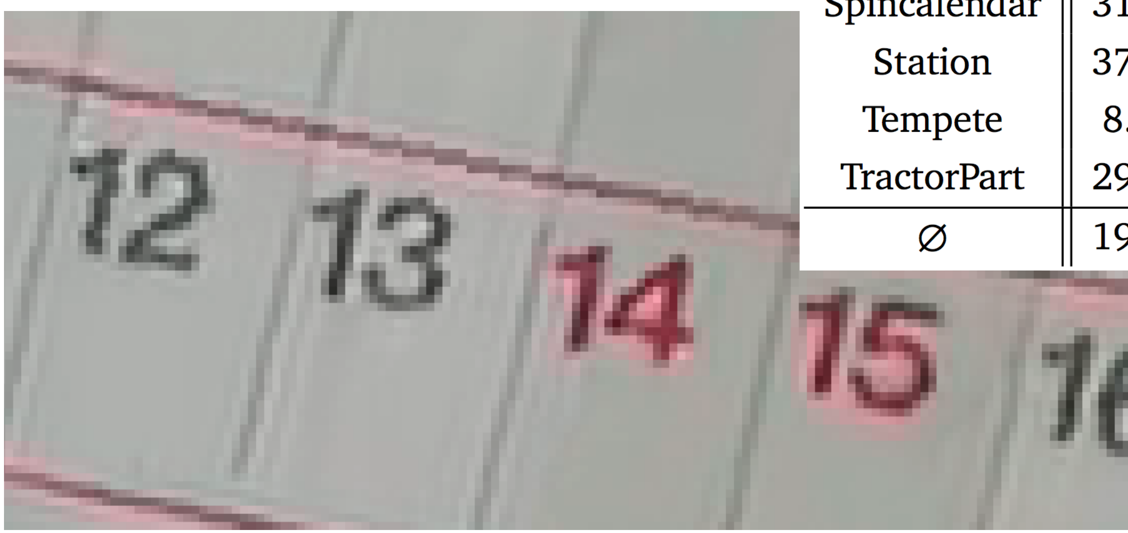


		Area [%] coded with inter prediction mode					
		HOMC			HOMC+BBTSC		
Sequence	QP	AMVP	MRG	SKIP	AMVP	MRG	SKIP
Spincal.	28	64.8	13.0	21.1	41.8	24.6	32.5
	32	62.3	9.9	26.8	31.9	21.8	45.1
	36	50.0	7.5	41.5	23.0	14.6	61.3
	40	32.3	6.1	60.5	15.8	10.4	72.8
Station	28	58.8	7.4	31.9	15.1	16.4	66.6
	32	42.7	5.7	49.7	10.0	9.3	78.8
	36	28.5	5.1	64.7	7.9	7.2	83.2
	40	18.6	4.4	75.3	6.6	6.1	85.6
	∅	44.8	7.4	46.4	19.0	13.8	65.7

- AMVP
- Merge
- Skip

Evaluation – *pixelwise vs. 4x4-subpartition-wise compensation*





Sequence	Pixel-wise MC		4 × 4-pixel MC	
	Aff.	Z&R	Aff.	Z&R
BlueSky	11.1	12.5	9.4 (**-1.7**)	11.1 (**-1.4**)
BQSquare	5.7	6.9	5.3 (**-0.4**)	6.4(**-0.5**)
Cactus	9.2	9.7	8.0 (**-1.2**)	8.4 (**-1.3**)
Jets	17.0	21.3	16.1 (**-0.9**)	20.6 (**-0.7**)
ShieldsPart	21.2	26.3	19.7 (**-1.5**)	25.2 (**-1.1**)
SlideShow	18.8	16.0	14.3 (**-4.5**)	12.5 (**-3.5**)
Spincalendar	31.3	35.0	28.6 (**-2.7**)	32.4 (**-1.6**)
Station	37.5	41.8	36.5 (**-1.0**)	41.3 (**-0.5**)
Tempete	8.7	10.7	7.5 (**-1.2**)	9.6(**-1.1**)
TractorPart	29.0	32.9	27.9 (**-1.1**)	32.1(**-0.8**)
∅	19.0	21.3	17.3 (**-1.7**)	20.0 (**-1.3**)

Thank you for your attention!

Are there any questions?

References

[1] M. Narroschke and R. Swoboda, *Extending HEVC by an affine motion model*, in PCS, 2013, pp.321-324.

[2] Mathias Wien, *High Efficiency Video Coding – Coding Tools and Specification*, Springer, Berlin, Heidelberg, Sept. 2014.

[3] *HM14.0KTA1.0 software*, https://vceg.hhi.fraunhofer.de/svn/svn HMJEMSoftware/tags/HM-14.0-KTA-1.0.

[4] Cordula Heithausen and Jan Hendrik Vorwerk, *Motion Compensation with Higher Order Motion Models for HEVC*, in ICASSP, Brisbane, Australia, April 2015, IEEE.

[5] Cordula Heithausen Max Bläser, Mathias Wien and Jens-Rainer Ohm, *Improved Higher Order Motion Compensation in HEVC with Block-to-Block Translational Shift Compensation*, in ICIP, Phoenix, USA, September 2016, IEEE.

[6] C. Heithausen, M. Bläser, and M. Wien, *Distance Scaling of Higher Order Motion Parameters in an Extension of HEVC*, in *Proc. of International Picture Coding Symposium PCS '16*, (Nuremberg, Germany), IEEE, Piscataway, Dec. 2016.

[7] S. Pateux and J. Jung, *An excel add-in for computing bjontegaard metric and its evolution*, VCEG Doc. VCEG-AE07, January 2007.

[8] „Cat Walk practise“, sketch by Ida Mikkonen, 2009-2015.