JVET-H0031

Inter Prediction using Estimation and Explicit Coding of Affine Parameters

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Outline

- Introduction
- Quantization and Coding of Affine Parameters
- Affine Motion Transformation and Estimation of Matrix Parameters
- **Block-to-Block Translational Shift Compensation - BBTSC**
- **Higher Order Distance Scaling - HODS**
- Evaluation
- Conclusion

Introduction: Higher Order Motion Compensation

- **Higher Order Motion Compensation (HOMC)**
  - Block-wise option of additional parameters describing non-transl. motion (RD-decision)
  - Pixel-wise compensation (4×4 MC tested as well)
    - sub-sample interpolation with $^1/_{16}$ pixel precision
  - Prediction improving tools: BBTSC, HODS
  - Implementation in HM14.0-KTA1.0[3]

- **Differences to affine mode in JEM**
  - **Direct coding of affine matrix parameters instead of mapping them to translation vectors**
  - Temporal prediction of affine motion
  - Pixelwise compensation

- **Benefits of direct coding of affine matrix parameters**
  - Avoidance of multiple conversions between affine parameters and translational *control point motion vectors* (precision loss due to quarter-pel rounding)
  - Less bit-depth precision necessary due to a smaller value range of parameters
  - Temporal scaling can be done correctly (→ HODS)

Affine Motion Transformation & Estimation of Affine Matrix Parameters

- Full and simplified affine motion transformation matrix

$$\boldsymbol{x}_{k-1} = \boldsymbol{A} \cdot \boldsymbol{x}_k$$

$$\begin{pmatrix} x_{k-1} \\ y_{k-1} \\ 1 \end{pmatrix} = \begin{pmatrix} a_2 & a_4 & a_0 \\ a_5 & a_3 & a_1 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} x_k \\ y_k \\ 1 \end{pmatrix}$$

$$\boldsymbol{A}_{\text{fullAff}} = \begin{pmatrix} a_2 & a_4 & a_0 \\ a_5 & a_3 & a_1 \\ 0 & 0 & 1 \end{pmatrix}$$

$$a_3 = a_2$$
$$a_4 = -a_5 =: a_3'$$

$$\boldsymbol{A}_{\text{simpAff}} = \begin{pmatrix} a_2 & a_3' & a_0 \\ -a_3' & a_2 & a_1 \\ 0 & 0 & 1 \end{pmatrix}$$

- Iterative estimation method based on temporal and spatial local gradients[1][4]
    - Initialized by block-matching result

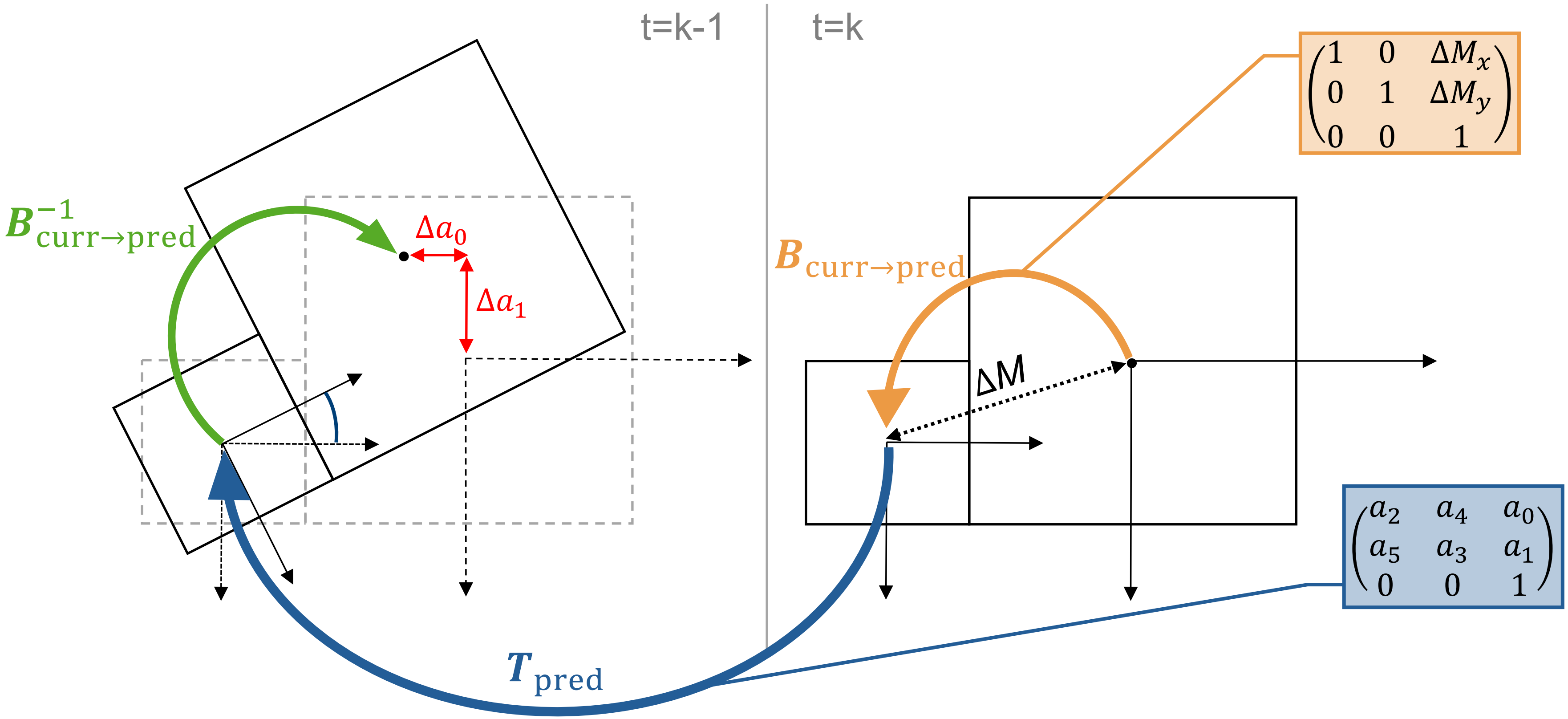
[1] M. Narroschke and R. Swoboda, *Extending HEVC by an affine motion model*, in PCS, 2013.
[4] Cordula Heithausen and Jan Hendrik Vorwerk, *Motion Compensation with Higher Order Motion Models for HEVC*, in ICASSP, 2015.

Quantization and Coding of Affine Parameters[4]

- Affine parameters represented in block-wise coordinate system
- Values of non-translational matrix parameters range between $0 < a_2, a_3 < 2$ and $-1 < a_4, a_5 < 1$
- Fine uniform quantization of higher order parameters $a_{p>1}$ with quantization factor $q_{\mathrm{ho}} = 256$
- 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 (larger zero, larger one, larger two, remainder, sign flag)
  - 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.

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



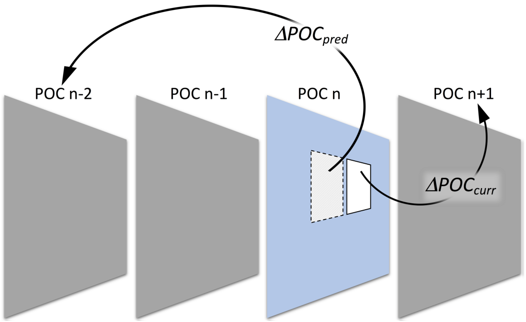
$$\hat{T}_{\text{curr}} = B^{-1}_{\text{curr}\rightarrow\text{pred}} \cdot T_{\text{pred}} \cdot B_{\text{curr}\rightarrow\text{pred}} = \begin{pmatrix} a_2 & a_4 & a_0 + \boxed{\Delta M_x(a_2 - 1) + \Delta M_y a_4} \\ a_5 & a_3 & a_1 + \boxed{\Delta M_x a_5 + \Delta M_y (a_3 - 1)} \\ 0 & 0 & 1 \end{pmatrix}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

[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]

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

$$\boldsymbol{A} =: \boldsymbol{A}_{\text{rot}} \boldsymbol{A}_{\text{shear}} \boldsymbol{A}_{\text{scale}} = \begin{pmatrix} \cos\varphi & -\sin\varphi \\ \sin\varphi & \cos\varphi \end{pmatrix} \begin{pmatrix} 1 & k \\ 0 & 1 \end{pmatrix} \begin{pmatrix} s_x & 0 \\ 0 & s_y \end{pmatrix}$$



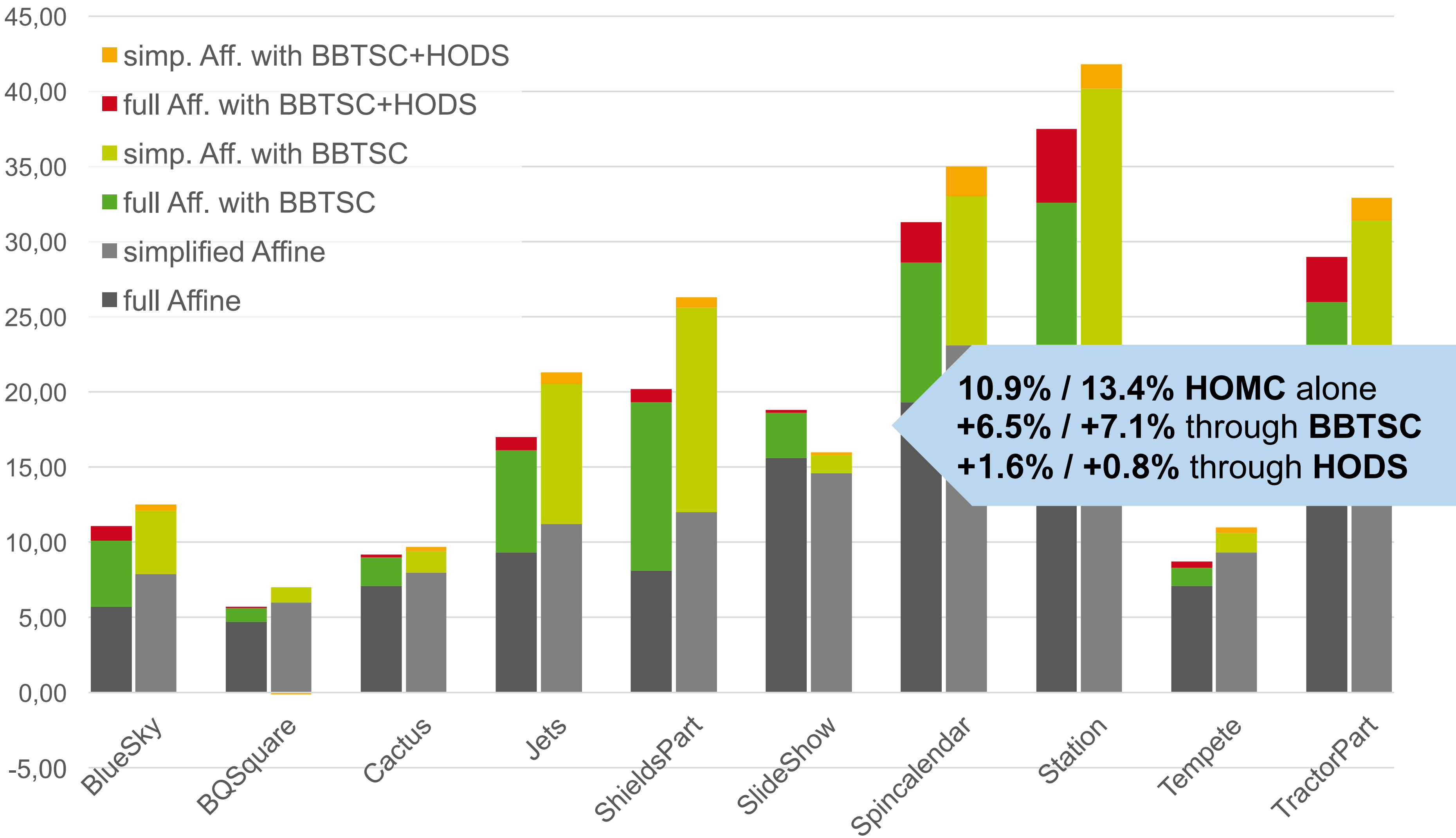
$D = -0.5$

1. Determination of distance scaling factor $D = \frac{\Delta POC_{\text{curr}}}{\Delta POC_{\text{pred}}}$.
2. Decomposition of non-translational matrix $\boldsymbol{A}$ 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 $\widetilde{\boldsymbol{A}} = \begin{pmatrix} \tilde{a}_2 & \tilde{a}_4 \\ \tilde{a}_5 & \tilde{a}_3 \end{pmatrix}$.

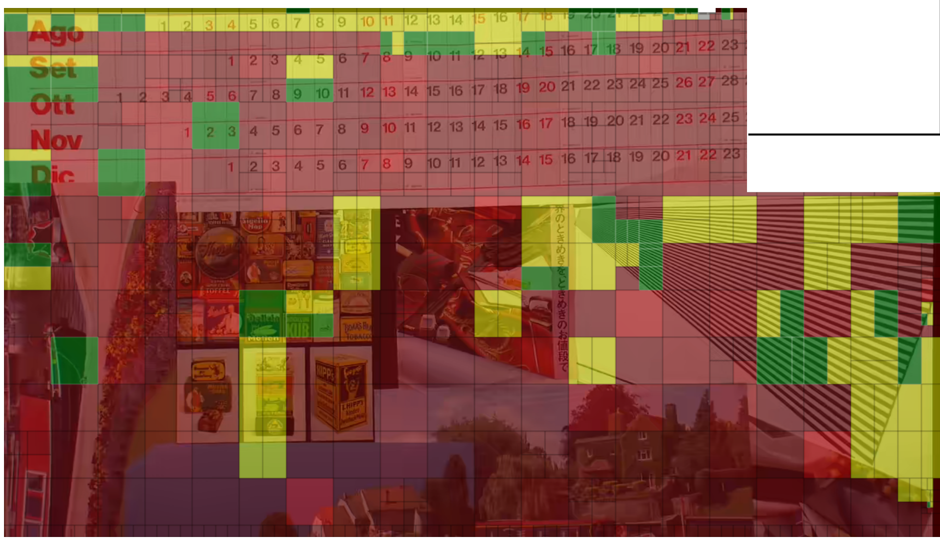
$$\tilde{\varphi} = D \cdot \varphi$$
$$\tilde{k} = D \cdot k$$
$$\tilde{s}_x = s_x^D$$
$$\tilde{s}_y = s_y^D$$

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

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



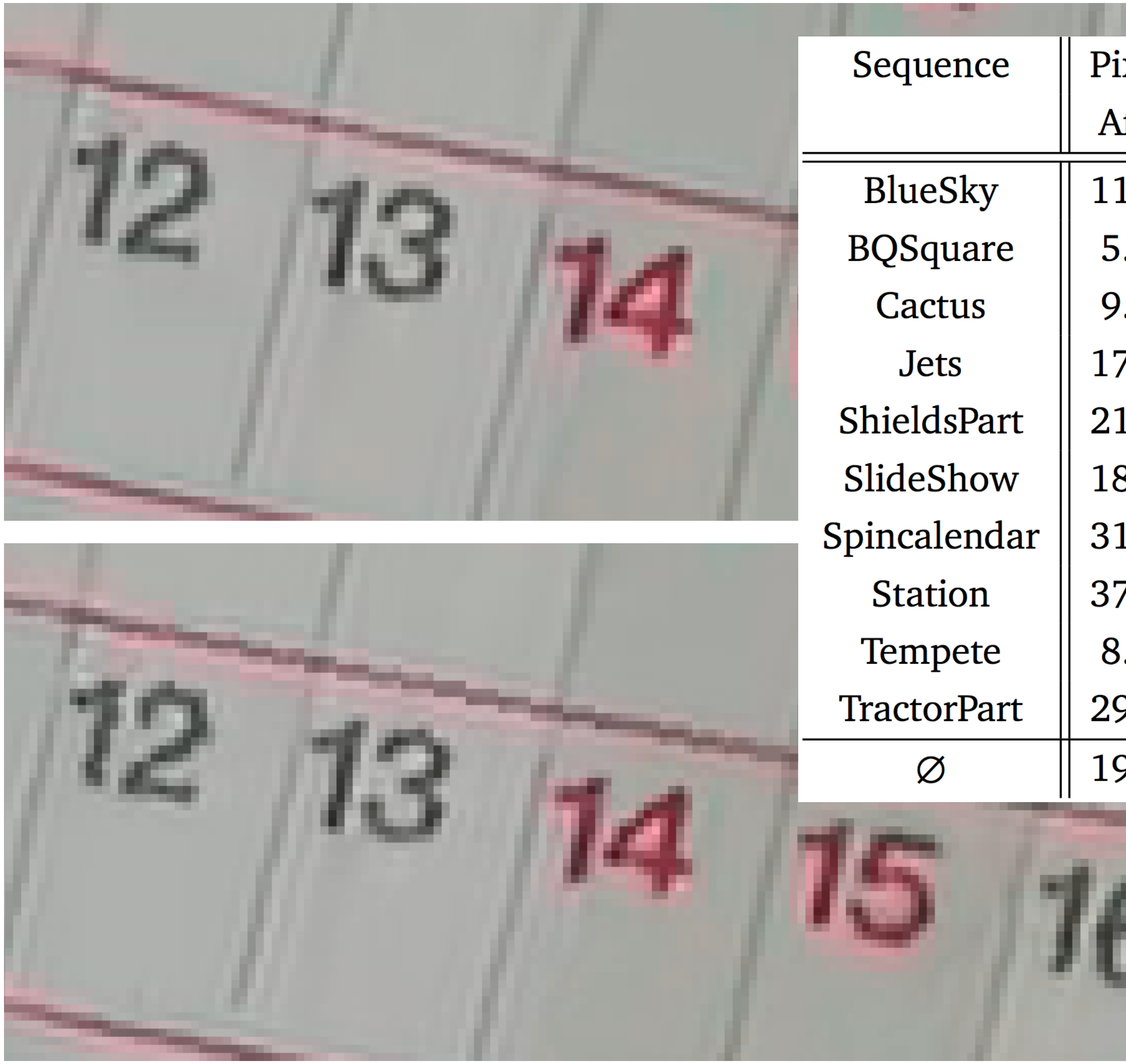
Evaluation – *Prediction mode occurrences with/without BBTSC*



Sequence	QP	Area [%] coded with inter prediction mode: HOMC AMVP	HOMC MRG	HOMC SKIP	HOMC+BBTSC AMVP	HOMC+BBTSC MRG	HOMC+BBTSC 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**)

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Rate Reduction for Different Coding Configurations

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**

Conclusion

- **Higher order motion compensation system**
  - 2 or 4 additional parameters (affine motion model)
    - estimated from temporal and spatial local gradients
    - affine matrix parameters directly coded
  - improved prediction through
    - **BBTSC**
    - **HODS**
- **Average bit-rate reduction of about 20% over HM14.0 KTA1.0** for higher order motion content in low delay P mode

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.