

**JVET-H0031**

# **Inter Prediction using Estimation and Explicit Coding of Affine Parameters**

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# Outline

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- 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
- Conclusion


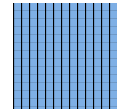
# Introduction: Motivation for Higher Order Motion Compensation

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- Conventional motion compensation (HEVC-compliant)<sup>[2]</sup> **only translational**
  - 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 (RD-decision)
  - Implementation in HM14.0-KTA1.0<sup>[3]</sup>
  - Adaptation of coder
    - higher precision sub-sample interpolation and quantization
    - BBTSC, HODS
  - **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 estimation method based on temporal and spatial local gradients<sup>[1][4]</sup>

$\partial s_{k-1}(x)/\partial x$ 



reference block k-1 k current block

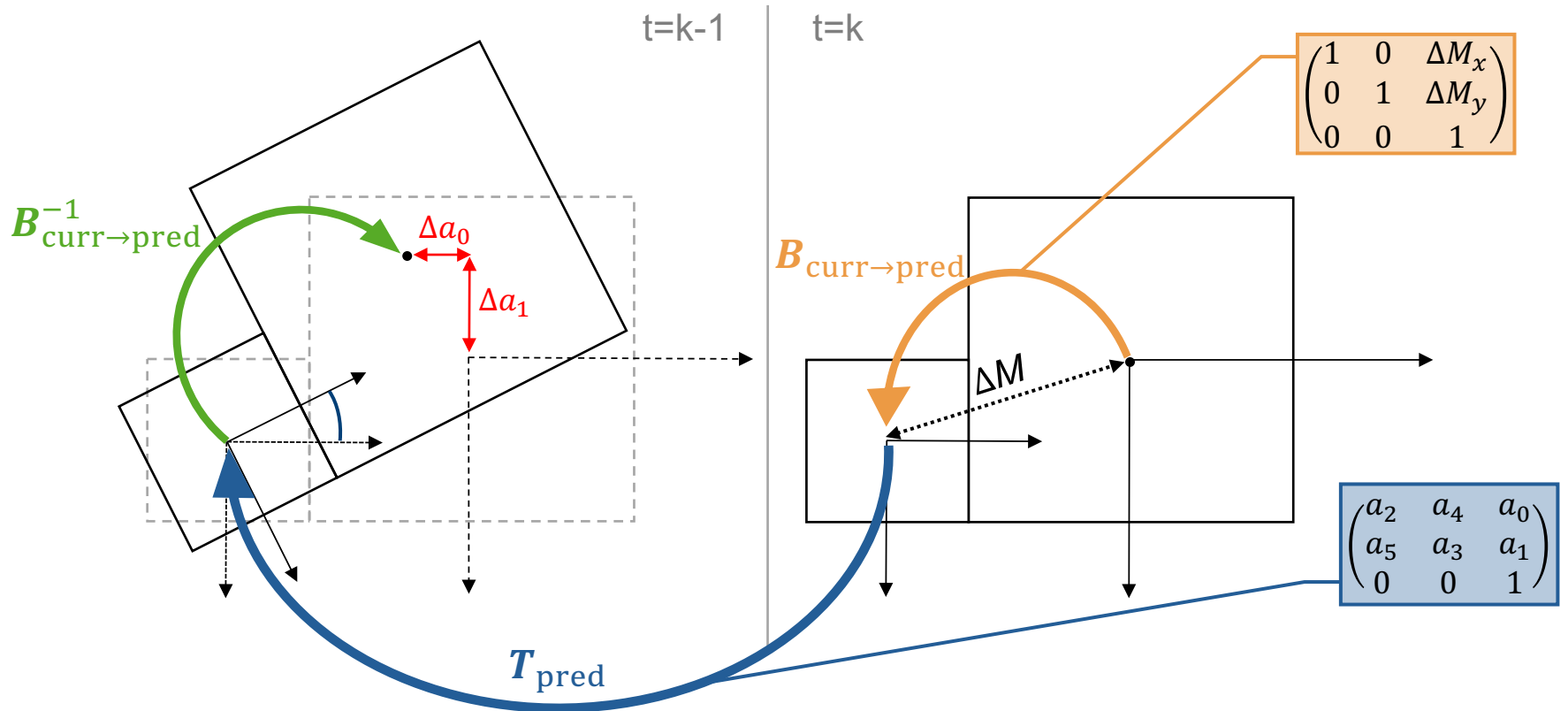
$$\underbrace{\begin{pmatrix} g_t(x_0) \\ g_t(x_1) \\ \vdots \\ g_t(x_{N-1}) \end{pmatrix}}_{\mathbf{G}_t} = \underbrace{\begin{pmatrix} \mathbf{h}^T(x_0) \\ \mathbf{h}^T(x_1) \\ \vdots \\ \mathbf{h}^T(x_{N-1}) \end{pmatrix}}_{\mathbf{H}} \cdot \underbrace{\begin{pmatrix} a_0 \\ a_1 \\ \vdots \\ a_{P-1} \end{pmatrix}}_{\Delta \mathbf{a}} \Rightarrow \Delta \mathbf{a} = \mathbf{H}^+ \cdot \mathbf{G}_t$$

$$\Delta \mathbf{a} = \sum_{i_{it}}^I \Delta \mathbf{a}^{(i_{it})}$$

[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<sup>[5]</sup>



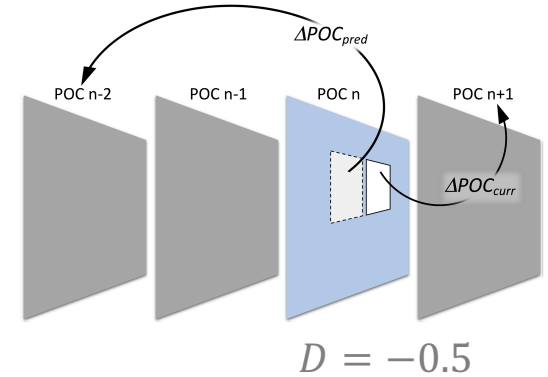
$$\hat{T}_{curr} = B_{curr \rightarrow pred}^{-1} \cdot T_{pred} \cdot B_{curr \rightarrow pred} = \begin{pmatrix} a_2 & a_4 & a_0 + \Delta M_x(a_2 - 1) + \Delta M_y a_4 \\ a_5 & a_3 & a_1 + \Delta M_x a_5 + \Delta M_y(a_3 - 1) \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} \Delta a_0 \\ \Delta a_1 \end{pmatrix}$$

[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<sup>[6]</sup>

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

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



1. Determination of distance scaling factor  $D = \frac{\Delta POC_{\text{curr}}}{\Delta POC_{\text{pred}}}$ .
2. Decomposition of non-translational matrix  $\mathbf{A}$  into higher order motion components  $\varphi, s_x, s_y, k$ .
3. Distance scaling of  $\varphi, s_x, s_y$  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  $\tilde{\mathbf{A}} = \begin{pmatrix} \tilde{a}_2 & \tilde{a}_4 \\ \tilde{a}_5 & \tilde{a}_3 \end{pmatrix}$ .

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

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

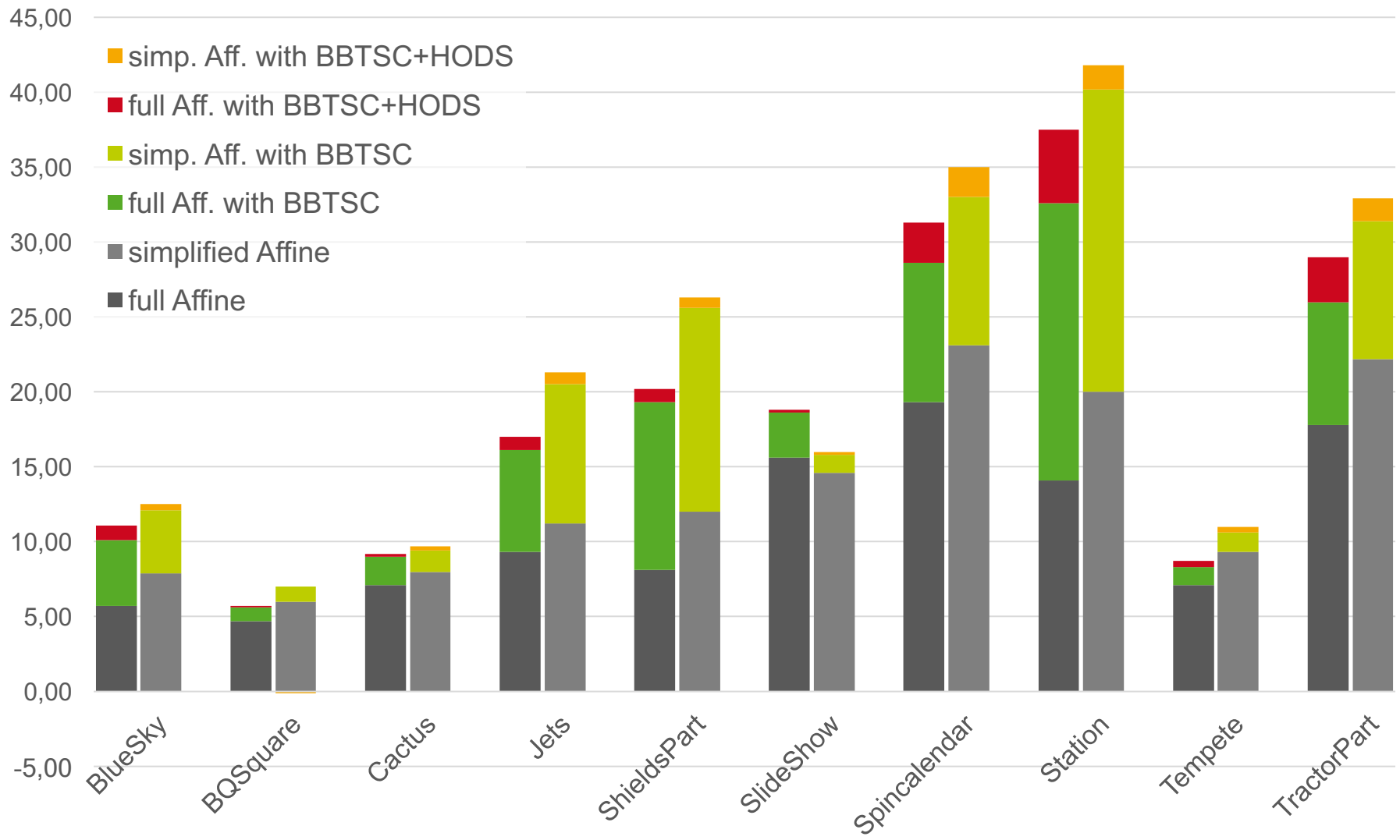
# Quantization and Coding of Affine Parameters<sup>[4]</sup>

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- Affine parameters represented in block-wise coordinate system
- Fine uniform quantization with quantization factor  $q > 4$ , here  $q_{\text{aff}} = 256$
- 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

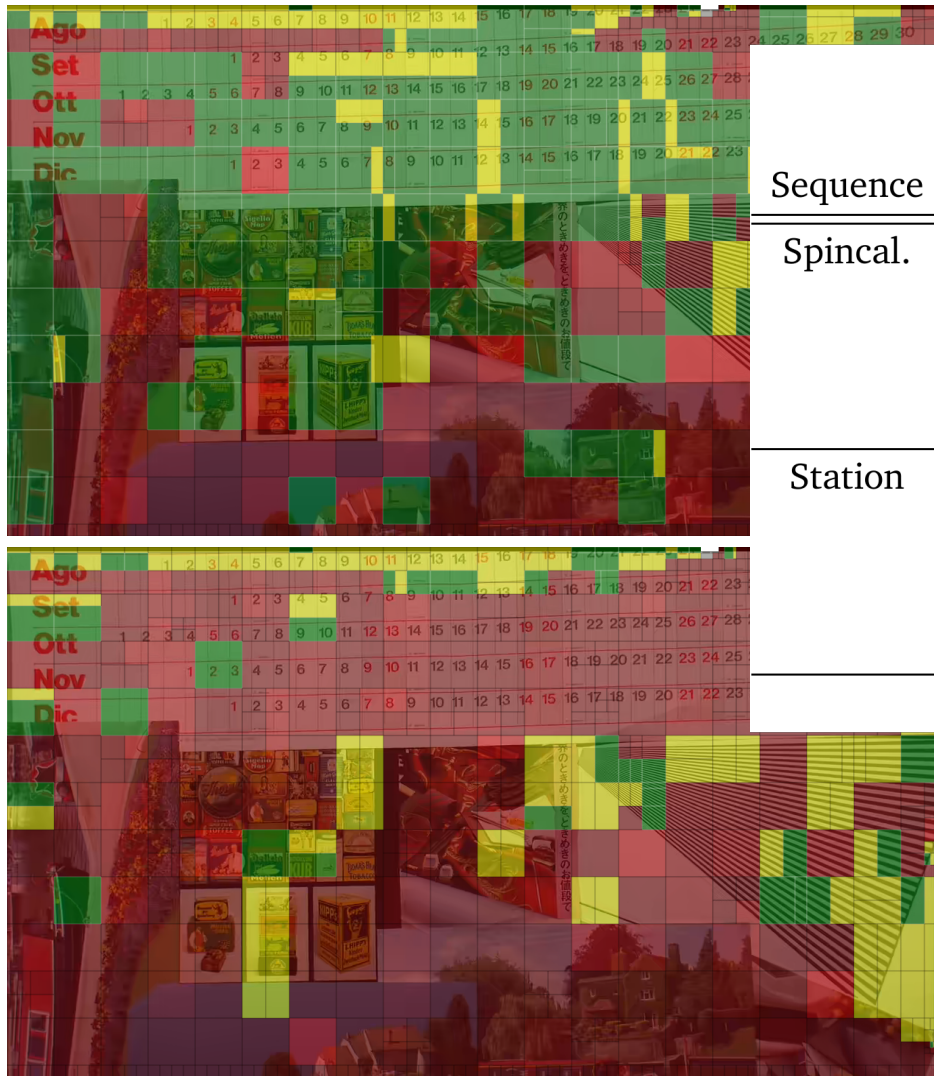
[4] Cordula Heithausen and Jan Hendrik Vorwerk, *Motion Compensation with Higher Order Motion Models for HEVC*, in ICASSP, Brisbane, Australia, April 2015, IEEE.

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





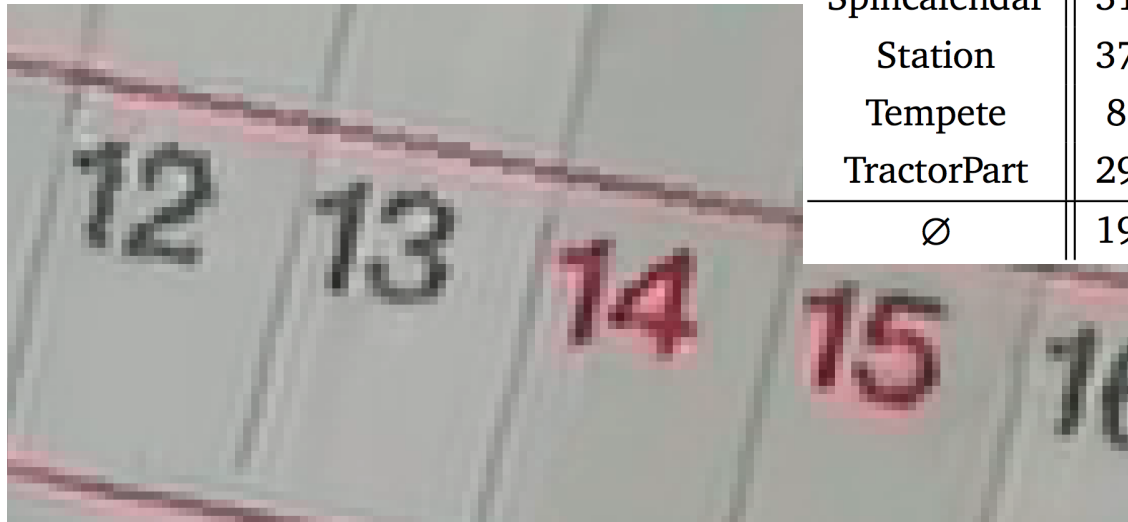
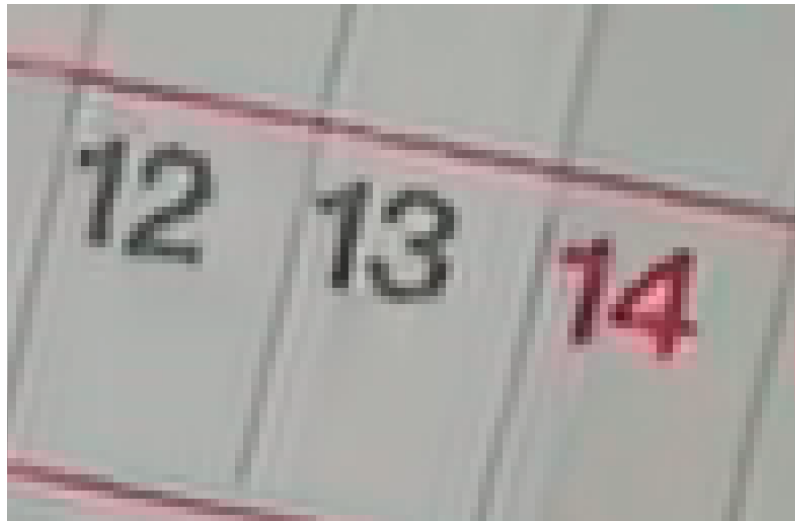
# Evaluation – Prediction mode occurrences with/without BBTSC



Sequence	QP	Area [%] coded with inter prediction mode			Area [%] coded with inter prediction mode		
		HOMC			HOMC+BBTSC		
		AMVP	Merge	SKIP	AMVP	Merge	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
	Ø	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)
Ø	19.0	21.3	17.3 (-1.7)	20.0 (-1.3)

# Conclusion

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- **Higher order motion compensation system**
  - 2 or 4 additional parameters (affine motion model)
    - estimated from temporal and spatial local gradients
    - explicitly 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.