Adaptive Colour-Space Selection in High Efficiency Video Coding

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***Abstract*—Recent developments in the standardisation of High Efficiency Video Coding (HEVC) have shown that the block-wise activation/deactivation of a colour transform can significantly improve the compression performance. This coding tool is based on a fixed colour space which is either YCgCo in lossy compression mode or YCgCo-R in the lossless mode.**

The proposed method shows that the performance can be increased even more when the colour space is not fixed but selected dependent on the image characteristic. Improvements of more than 2% can be achieved in lossless intra coding if the colour space is automatically chosen once for the entire image. In lossy intra compression, the performance can also be increased if a proper colour space is chosen.

I. Introduction

The success of image-compression methods depends on, aside from other aspects, the exploitation of correlations between the colour components. In the course of the standardisation of HEVC [1], several tools have been proposed for this purpose. The two most effective tools are cross-component prediction (CCP, [2]) and adaptive colour transform (ACT, [3]). During the rate-distortion optimisation, the latter checks after the prediction stage for each transform unit (TU) whether the coding of this predictive residual would benefit from the colour transform. If yes, then the unit is converted to another colour space before it is further processed. In the lossy compression mode, the colour space is YCgCo, in lossless mode it is YCgCo-R [4], [5].

The big advantage of a block-wise activation of the colour space conversion becomes especially obvious for images with mixed content. These images consist not only of camera-captured content but also contain synthetic data like diagrams, flow charts, text etc. In synthetic regions, transforming the data into a colour space like YCgCo often has an adverse effect and it should be disabled.

In combination with lossless compression methods for still image coding (JPEG-LS [6], JPEG2000 [7]), it could be shown that the adaptive selection of the colour space benefits the compression results ([8]–[10]) and a procedure for the automatic selection had been proposed [8].

This paper proposes a low-complexity method for the automatic determination of a suitable colour space in the context of lossless HEVC and shows the benefits for the compression performance. Only seven bits overhead are required for signalling the selection. In addition the investigations are extended towards lossy compression.

The outline is as follows: Section II presents the basics of reversible and irreversible colour transforms. Section III-A explains the implementation details with respect to the automatic selection and the modification to the anchor system. The investigations and the results are discussed in Section IV. A summary is given in Section V.

II. Basics of colour transforms

This section briefly explains the theoretical background of colour-space conversions and introduces the colour spaces that have been used in the investigations.

The idea of changing the colour space from RGB to something else is basically decorrelation. It is intended to decrease the signal entropy. In addition, the luminance (Y) information is separated from chrominance (UV) information, which can be of importance if these components shall be processed in a different manner.

The conversion from one colour-space to another is performed using a colour transform. It must be differentiated between reversible transforms that do not change the signal information and irreversible transforms where the information can be changed due to rounding operations.

A. Reversible colour transforms

Reversible transformations can be achieved most easily by using a lifting structure [11]. The underlying idea is to operate on a poly-phase representation of the signal to be transformed. Signal values from one phase are combined in a certain manner and added to the values of another phase. The combination is completed with rounding of these intermediate results to integer numbers (integer lifting).

The structure of the YCgCo-R transform is depicted in **Figure 1**. The three signals containing the values R, G, and B can be interpreted as poly-phases of a colour signal. The rounding operations (not shown in the figure) appear directly after the multiplications with $1/2$. The reversibility can simply

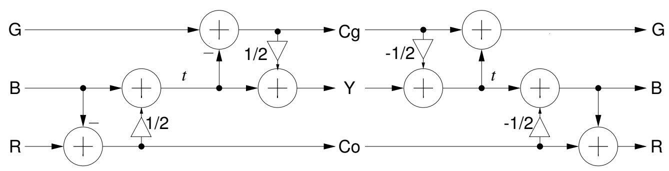

Fig. 1. Processing structure of the transformation from RGB to YCgCo-R colour space and back.

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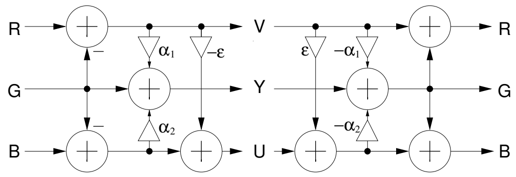

Fig. 2. Processing structure of the transformation from RGB to Ay_uv colour spaces proposed in [8].

be proven based on the corresponding equations. The forward transformation is

$$\begin{aligned} \mathsf{Co} &= \mathsf{R} - \mathsf{B} \\ t &= \mathsf{B} + (\mathsf{Co} >> 1) \\ \mathsf{Cg} &= \mathsf{G} - t \\ \mathsf{Y} &= t + (\mathsf{Cg} >> 1) \end{aligned} \quad (1)$$

and the backward transformation is realised by reversing the order of equations and transforming them to the desired variable:

$$\begin{aligned} t &= \mathsf{Y} - (\mathsf{Cg} >> 1)\ , \\ \mathsf{G} &= \mathsf{Cg} + t\ , \\ \mathsf{B} &= t - (\mathsf{Co} >> 1)\ , \\ \mathsf{R} &= \mathsf{B} + \mathsf{Co}\ . \end{aligned} \quad (2)$$

In [8], another simple structure had been proposed (**Figure 2**). Using different values for α_1, α_2, ε taken from the set $\{0; 0.25; 0.5\}$ and permutations of the RGB input, 108 different transformations can be realised, including the YCgCo-R.

All derivable reversible colour spaces have in common that two of the three components show an increased bit depth. The 24-bit-input RGB signal is transformed to a 26-bit YUV signal.

This set can be supplemented by nine simple colour spaces showing not two but a single chrominance component, see [8] for details. Here, only one component requires nine bits.

B. Irreversible colour transforms

In application to lossy compression, it is not required that the colour-space conversion is reversible. Instead, it is desired to keep the original bit depth. The ACT tool of the standard HEVC uses YCgCo because of its good decorrelation properties and simple implementation

$$\begin{aligned} \mathsf{Co} &= (\mathsf{R} - \mathsf{B}) >> 1 & \mathsf{R} &= \mathsf{Y} - \mathsf{Cg} + \mathsf{Co} \\ \mathsf{Cg} &= (2 \cdot \mathsf{G} - \mathsf{R} - \mathsf{B}) >> 2 & \mathsf{G} &= \mathsf{Cg} + \mathsf{Co} \\ \mathsf{Y} &= (2 \cdot \mathsf{G} + \mathsf{R} + \mathsf{B}) >> 2 & \mathsf{B} &= \mathsf{Y} - \mathsf{Cg} - \mathsf{Co} \end{aligned} \ .$$

III. Implementation details

A. Automatic selection

During the rate-distortion optimisation procedure, the standard ACT tool processes each transform unit twice, one time without the colour-space conversion and one time using the conversion, which nearly doubles the processing costs. This approach cannot be followed if we have more than one hundred colour spaces to be tested. Instead, the entire actual frame is inspected once in order to find a suitable colour space. In principle, the approach of [8] is used with a small modification. Firstly, the frame is converted into a prediction residual using the median adaptive prediction (MAP) [13]. This simulates the fact that, in HEVC, the colour transform is applied to the prediction error. Secondly, all colour spaces are tested. The computational costs remain low, since many colour spaces share the same Y computations and UV computations and only their combination is different. While in [8] an entropy criterion had been used, our investigations showed slightly better results (with respect to the compression performance) when comparing the energies of the colour-transformed prediction residuals.

The colour space leading to the smallest energy is selected and seven bits are included in the code stream indicating the selection.

B. Modification of QP values

TABLE I
POSSIBLE NORMS OF REVERSIBLE COLOUR TRANSFORMS AND ASSIGNED QP OFFSETS.

norm	ΔQP
0.7071	−3
1.0000	0
1.2247	2
1.2747	3
1.4142	5

As the forward colour transform is not normalised, the energy of the converted prediction residual is changed when the colour-space transform is applied. In order to compensate such change for the three colour components, Zhang et al proposed in [3] to modify the quantisation parameter (QP value) in lossy compression by a certain offset. This concept must be adopted for all colour spaces used in our investigations. **Table I** shows the possible norms and the corresponding QP offsets (ΔQP) that are chosen.

IV. Investigations

The effect of the adaptive selection of the colour spaces compared to the simple on/off switching of the YCgCo(-R) transform can be shown best when competing coding tools (intra-block copy, cross component prediction, palette mode) are disabled. The additional computation time for the automatic selection is negligible compared to the other processing steps. An average increase of 0.5% has been measured.

A. Test data

The investigations have been performed using 46 test images from different sources [14]. This broadens the variety compared to the limited set of sequences used in the HEVC standardisation. The set is a mixture of camera-captured data, synthetic data, and mixed content. As the proposed method do not exploit dependencies between frames, the investigations can be limited to still images.

When the original format of the images was RGB, the order of components has been changed inside HEVC to GBR using the RGBtoGBR flag in the configuration file as this is the expected order of colour components in HEVC.

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B. Lossless compression

Table II contains the compression results in lossless mode using reversible colour spaces.

The column on the left side contains the file name of the image. The next two columns show the percentage of pixels that are converted into the YCgCo-R colour space, when using the standard colour transform, and the corresponding size of the compressed file in bytes. For camera-captured content the percentage is typically high since it is advantageous to convert the RGB data into the YCgCo-R colour space. If YCgCo-R is not used, but an automatically selected colour space ('RCT'), then the compression result is improved for all but three images (columns under 'Automatic'). In total, the savings are 2.02%, which is impressive for such a low-complex technique. A brute force approach reveals that the automatic selection has the potential to be improved. For most images, there is a colour space that is more suitable (i.e., leads so a smaller compressed file) than the automatically chosen one, providing savings of 3.12% on average. The gap of about 1% is caused by the fact that the automatic selection tries to find an optimum for the entire frame, while the transform is finally only performed for a subset of blocks.

The test also contains data that are already in a YUV colour space. As can be derived from the listed results, these images should use a colour space that does not compute two difference signals. The colour-space number 117, for instance, corresponds to

$$\mathsf{Y}' = \mathsf{Y}, \quad \mathsf{U}' = (\mathsf{U} + \mathsf{V}) >> 1, \quad \mathsf{V}' = \mathsf{Y} - \mathsf{U}\,. \tag{3}$$

In principle, the efforts for selecting a suitable colour space could be even dropped by limiting the number of candidates to the most promising ones. A more detailed discussion of the different colour spaces can be found in [8].

The compression results highly correlate with the percentage of the transformed pixel. The highest difference can be seen for image 'p30_orig_1280x1600'. The YCgCo-R colour space seems not to be appropriate for this image, as only 28.66% is transformed. When using the colour-space number 115, this percentage reaches 99.93%.

C. Lossy Compression with RCT

The success of adaptive colour-space selection in lossless compression raises the question whether it also can benefit lossy compression. The application of reversible colour spaces has been tested first in combination with moderate quantisation (QP$\in$ $\{3, 6, 9, 12\}$) which is close to lossless compression. **Table III** contains the corresponding results. It comprises again three parts: one for the standard setting using YCgCo, one for the automatic selection of a colour space, and one part showing the results for the best colour space. The investigations with automatic selection of a suitable colour space have then be extended using operation points with stronger quantisation (QP={9,12,17,22}).

1) Percentage of transformed pixels: All three parts show the percentage of pixels that have been transformed. The values corresponding to the investigations with QP=12 have representatively been chosen. It can be seen that the percentage of transformed pixel is in almost all cases higher than in the standard setting when the best colour space is used. The percentage is generally low for the *.yuv images since their colour components have already been decorrelated and the possible improvement by another colour transforms is rare.

2) Colour spaces: The columns entitled with 'RCT' show the used reversible colour spaces. In the automatic mode, these spaces are the same as in Table II since the selection is independent on the compression mode. Aside from the RCT 117 which has already been explained in Section IV-B, the colour space 61 seems to be quite useful. It computes

$$\mathsf{V} = \mathsf{R} - \mathsf{B}, \quad \mathsf{Y} = \mathsf{B} + (\mathsf{V} >> 1), \quad \mathsf{U} = \mathsf{G} - \mathsf{Y}\,. \tag{4}$$

3) Performance: The columns 'x/y' in the automatic mode contain the Bjøntegaard rate [15] for the three image components. Negative values indicate an improvement compared to the standard setting. For the three components of a single image, the changes are not always positive or always negative. The reason lies in the fact that the components are differently treated depending on the selected colour space.

Column 'mean' is simply the average of the three values. The investigations based on the second set of QP values show divergent results. The performance drops for the top 32 images, while it stay nearly the same for the other images.

The last three columns on the right contain the result of a brute-force test including all 118 colour spaces from [8] (including RGB). For all but one image (sc_console_1920x 1080_60_8bit_444.yuv), the performance can be significantly improved by using a proper colour space.

The automatic selection obviously fails to find a suitable colour space for some images. Especially the results of the images 'feed_content…', 'Science_Wraps…', 'Screen-Shot-2013-_…', and 'topcategorychart…' prevent a satisfying average result for the top 32 images in the automatic colour-space-selection mode.

V. Summary and Conclusions

The investigations have shown that (i) the adaptive selection of the colour space significantly improves the performance of lossless and lossy compression using HEVC compared to the simple switch-on/off mechanism used in [3] and (ii) the automatic selection of a suitable colour space is possible. However, there is still a distinct performance gap between the automatically selected colour space and the colour space that leads to maximum compression. One major reason probably is the fact that the automatic selection inspects the entire image while the rate-distortion (RD) optimisation of HEVC decides to switch off the colour-space conversion for some image blocks. It is assumed that the automatic selection could be improved if it can be qualified to mimic the RD decisions more precisely. In addition, it should be taken into account whether the compression mode is lossless or lossy, since the best colour spaces are mostly different when comparing these two modes.

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TABLE II
COMPRESSION RESULTS IN LOSSLESS MODE, SEE TEXT FOR DETAILS

	YCgCo-R		Automatic			Best		
image	% transf.	Bytes	RCT	% transf.	Bytes	RCT	% transf.	Bytes
5colors_544x544.raw	10.69%	29771	97	10.69%	29772	23	14.49%	27807
bike_orig_1280x1600.raw	94.18%	3221010	27	94.91%	**3161383**	27	94.91%	*3161383*
cafe_orig_1280x1600.raw	76.23%	3977308	58	79.62%	**3941699**	34	83.10%	3911280
feed_content_bb_616x456.raw	51.50%	**140814**	3	44.69%	155964	13	52.26%	137877
house_o_2272x1704.raw	99.51%	5051615	95	99.61%	**5002367**	70	99.69%	4909684
p01_orig_1280x1600.raw	99.62%	2582726	26	98.43%	**2462785**	26	98.43%	*2462785*
p04_orig_1280x1504.raw	89.11%	2641808	57	93.67%	**2630067**	9	97.58%	2601156
p06_orig_1280x1600.raw	86.89%	2448299	27	96.90%	**2300721**	27	96.90%	*2300721*
p10_orig_1280x1600.raw	99.70%	2141185	51	98.36%	**2134061**	15	98.71%	2128902
p14_orig_1280x1600.raw	93.21%	2549484	24	98.20%	**2374567**	16	97.90%	2371783
p22_orig_1280x1504.raw	98.49%	2407512	11	97.75%	**2383246**	11	97.75%	*2383246*
p30_orig_1280x1600.raw	28.66%	2698798	36	39.19%	**2581783**	115	99.93%	2382136
Science_Wraps_2010_944x784.raw	13.36%	496997	36	19.22%	**490085**	28	19.93%	469027
Screen_content_art_352x240.raw	9.30%	18269	3	17.58%	**17309**	3	17.58%	*17309*
screen-capture_600x448.raw	66.70%	**161800**	51	67.88%	163180	13	67.04%	160276
Screen-Searchmetri_968x576.raw	7.97%	72157	51	9.72%	**70220**	15	12.59%	68361
Screen-Shot-2013-_1424x888.raw	9.88%	110823	3	11.44%	**109528**	8	11.41%	108466
Screen-shot-2013-0_584x576.raw	31.83%	71105	3	33.54%	**68578**	4	30.84%	66796
Screen-Shot-2015-0_688x456.raw	21.90%	192388	63	33.86%	**189227**	27	48.36%	185589
shipbig_o_1440x1152.raw	68.61%	2873188	108	65.11%	**2863104**	108	65.11%	*2863104*
stadtplan-museum-o_880x600.raw	68.66%	453053	87	70.95%	**428116**	55	70.60%	423095
SUFig-57_472x472.raw	26.72%	35854	102	25.65%	**35595**	26	33.88%	33247
sunflower_456x416.raw	99.00%	286700	60	99.55%	**279170**	12	99.58%	278061
topcategorychart_856x480.raw	14.67%	44022	3	14.57%	**42933**	6	14.13%	42394
tux-agafix_1200x1640.raw	22.21%	292312	39	26.84%	**269993**	39	26.84%	*269993*
Windows-Live-Write_376x248.raw	3.55%	25283	51	7.72%	**24832**	27	15.53%	24409
WOBIB_140_416x416.raw	61.69%	29979	3	74.10%	**22267**	3	74.10%	*22267*
wolf_536x360.raw	97.96%	155343	46	98.29%	**150226**	96	98.65%	149328
woman_orig_1280x1600.raw	99.65%	3022004	63	99.73%	**2986745**	99	99.78%	2983945
worddavf15bfb5a46c_592x312.raw	9.42%	10611	2	9.59%	**10427**	2	9.59%	*10427*
XchatScreenshot2__1016x696.raw	26.00%	108771	12	24.74%	**104421**	4	24.70%	99899
Z-scheme_(cs)_808x280.raw	16.65%	29252	4	19.74%	**27243**	4	19.74%	*27243*
sc_console_1920x1080_60_8bit_rgb.rgb	17.40%	236689	77	17.66%	**235464**	3	23.52%	227863
sc_desktop_1920x1080_60_8bit_rgb.rgb	20.21%	577327	51	23.15%	**565434**	3	28.56%	549537
sc_flyingGraphics_1920x1080_60_8bit_rgb.rgb	25.64%	**714106**	54	25.49%	714912	13	28.10%	699257
sc_map_1280x720_60_8bit.rgb	58.33%	746632	58	61.41%	**736406**	27	63.29%	725550
sc_robot_1280x720_30_8bit.rgb	81.23%	1096763	49	82.86%	**1090381**	13	86.08%	1083652
sc_SlideShow_1280x720_20_8bit.rgb	37.31%	312144	51	37.51%	**309268**	3	38.85%	306473
sc_web_browsing_1280x720_30_8bit_rgb.rgb	14.06%	254936	51	16.27%	**250547**	3	20.06%	245353
sc_console_1920x1080_60_8bit_444.yuv	8.53%	269649	117	9.53%	**271542**	49	8.54%	267278
sc_desktop_1920x1080_60_8bit_444.yuv	4.09%	586006	117	18.10%	**583031**	61	22.59%	582188
sc_flyingGraphics_1920x1080_60_8bit_444.yuv	4.09%	661171	117	16.01%	**652690**	117	16.01%	*652690*
sc_map_1280x720_60_8bit_444.yuv	0.61%	624557	114	5.45%	**623294**	117	16.51%	620818
sc_robot_1280x720_30_8bit_444.yuv	19.80%	890653	117	30.44%	**885447**	111	27.11%	882023
sc_SlideShow_1280x720_20_8bit_444.yuv	0.47%	255566	117	7.11%	**254026**	61	9.86%	254011
sc_web_browsing_1280x720_30_8bit_444_r1.yuv	0.43%	233028	117	10.50%	**231576**	57	15.33%	229357
total		45839468			44915632			44408046
reduction					2.02%			3.12%

For input images in YUV format, one should generally consider to use colour space 117 instead of YCgCo.

One important outcome of the investigations is that the proposed method has high potential not only in lossless compression, but can benefit the compression also in the lossy mode. Future research should address the question whether it might be helpful to use irreversible counterparts for all colour spaces as it is already implemented for YCgCo-R and YCgCo.

The variety of possible colour space could be decreased by identifying the most promising ones without losing much performance. The latter could probably be increased by selecting different colour spaces for different image regions. The signalling overhead would increase not too much, when it is integrated into the existing code-block structure.

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TABLE III
COMPARISON OF AUTOMATIC COLOUR-SPACE SELECTION AND YCgCo IN LOSSY MODE, SEE TEXT FOR DETAILS

		Automatic, QP={3,6,9,12}						Auto. QP=	Selection of		
	YCgCo			BD-rate (piecewise cubic)				{9,12,17,22}	best colour space		
Image	% transf.	RCT	% transf.	G/Y	B/U	R/V	Mean	Mean	RCT	% transf.	Mean
5colors_544x544.raw	8.06%	97	8.74%	4.53%	3.25%	0.42%	2.73%	-1.69%	89	9.30%	-3.84%
bike_orig_1280x1600.raw	78.78%	27	9.46%	2.75%	7.00%	8.99%	6.25%	27.41%	61	83.49%	-6.88%
cafe_orig_1280x1600.raw	52.82%	58	59.38%	-2.75%	-0.13%	-3.03%	-1.97%	-1.47%	61	69.42%	-4.59%
feed_content_bb_616x456.raw	41.06%	3	30.72%	15.27%	12.62%	10.03%	12.64%	15.74%	61	43.37%	-2.90%
Screen-Shot-2013-_1424x888.raw	86.41%	95	97.07%	-7.11%	-14.01%	-6.20%	-9.11%	-8.22%	72	98.01%	-13.70%
p01_orig_1280x1600.raw	94.62%	26	45.24%	-2.40%	14.34%	7.17%	6.37%	26.25%	72	97.00%	-15.26%
p04_orig_1280x1504.raw	70.34%	57	75.11%	-9.75%	1.35%	-8.43%	-5.61%	-1.36%	61	79.31%	-7.69%
p06_orig_1280x1600.raw	76.82%	27	51.16%	-5.00%	7.89%	10.16%	4.35%	10.92%	72	78.41%	-10.76%
p10_orig_1280x1600.raw	86.92%	51	92.85%	-16.03%	-5.05%	-16.33%	-12.47%	-2.79%	47	97.60%	-18.40%
p14_orig_1280x1600.raw	78.90%	24	85.78%	0.50%	-24.68%	-5.23%	-9.80%	-8.85%	72	96.96%	-18.27%
p22_orig_1280x1504.raw	92.22%	11	74.62%	5.38%	14.50%	-14.36%	1.84%	10.31%	47	94.61%	-10.40%
p30_orig_1280x1600.raw	9.75%	36	26.43%	-5.50%	-0.15%	1.35%	-1.43%	-2.67%	118	89.70%	-17.46%
Science_Wraps_2010_944x784.raw	11.06%	36	16.10%	31.73%	35.54%	36.53%	34.60%	28.06%	52	13.47%	-3.97%
Screen_content_art_352x240.raw	6.97%	3	8.73%	4.06%	3.25%	0.92%	2.74%	4.50%	87	9.20%	-1.50%
screen-capture_600x448.raw	38.60%	51	37.06%	-1.27%	-0.36%	-4.48%	-2.04%	-0.05%	61	38.11%	-6.09%
Screen-Searchmetri_968x576.raw	5.94%	51	6.83%	-1.42%	-2.05%	-4.63%	-2.70%	-1.52%	87	6.04%	-4.03%
Screen-Shot-2013-_1424x888.raw	6.54%	3	4.92%	15.81%	8.23%	-3.47%	6.85%	10.98%	56	6.12%	-4.75%
Screen-shot-2013-0_584x576.raw	21.83%	3	21.51%	2.54%	-5.65%	-10.73%	-4.61%	-3.54%	72	22.10%	-12.85%
Screen-Shot-2015-0_688x456.raw	31.22%	63	24.29%	-7.25%	1.69%	7.61%	0.68%	0.16%	1	88.57%	-8.75%
shipbig_o_1440x1152.raw	20.28%	108	36.18%	-2.32%	-0.10%	-1.09%	-1.17%	-1.57%	1	99.04%	-4.03%
stadtplan-museum-o_880x600.raw	56.83%	87	58.61%	-2.31%	-2.92%	-0.07%	-1.76%	-9.40%	72	58.04%	-5.12%
SUFig-57_472x472.raw	11.84%	102	12.02%	-4.79%	-4.43%	-2.97%	-4.06%	-4.39%	74	11.99%	-8.33%
sunflower_456x416.raw	79.56%	60	87.26%	-10.55%	9.35%	-10.77%	-3.99%	-0.96%	72	96.70%	-12.39%
topcategorychart_856x480.raw	7.42%	3	5.61%	12.85%	9.35%	3.29%	8.49%	13.38%	47	8.86%	-5.25%
tux-agafix_1200x1640.raw	14.73%	39	17.37%	-6.46%	-9.60%	-9.54%	-8.53%	-6.13%	72	17.59%	-8.98%
Windows-Live-Write_376x248.raw	4.48%	51	7.88%	-0.15%	-0.22%	-0.33%	-0.23%	1.19%	112	6.25%	-1.78%
WOBIB_140_416x416.raw	26.87%	3	34.29%	-10.95%	-12.15%	48.30%	8.40%	-16.15%	39	34.66%	-13.15%
wolf_536x360.raw	66.92%	46	73.17%	2.68%	-11.09%	-10.65%	-6.36%	-8.08%	72	85.27%	-16.94%
woman_orig_1280x1600.raw	87.33%	63	65.87%	-5.78%	-7.58%	7.67%	-1.90%	3.77%	61	92.86%	-8.02%
worddavf15bfb5a46c_592x312.raw	7.70%	2	8.02%	-2.33%	-9.13%	-2.33%	-4.60%	-20.37%	61	7.49%	-7.49%
XchatScreenshot2__1016x696.raw	17.12%	12	17.96%	0.31%	-0.70%	-2.95%	-1.11%	-3.58%	100	19.11%	-8.76%
Z-scheme_(cs)_808x280.raw	10.15%	4	10.33%	4.53%	8.22%	0.51%	4.42%	1.41%	77	10.52%	-2.09%
average							0.53%	1.60%			-8.58%
sc_console_1920x1080_60_8bit_rgb.rgb	12.19%	77	12.45%	-0.55%	-0.64%	-1.23%	-0.81%	-2.59%	87	12.94%	-1.38%
sc_desktop_1920x1080_60_8bit_rgb.rgb	15.55%	51	17.18%	-0.86%	-1.49%	-1.20%	-1.18%	-1.93%	39	17.13%	-2.00%
sc_flyingGraphics_1920x…8bit_rgb.rgb	15.78%	54	16.94%	0.63%	1.14%	-0.26%	0.50%	-0.16%	61	22.41%	-2.23%
sc_map_1280x720_60_8bit.rgb	47.37%	58	52.11%	-1.19%	2.99%	-2.64%	-0.28%	-0.01%	61	53.08%	-4.03%
sc_robot_1280x720_30_8bit.rgb	66.99%	49	72.74%	3.55%	-7.09%	-8.72%	-4.09%	-2.41%	61	72.52%	-7.02%
sc_SlideShow_1280x720_20_8bit.rgb	30.16%	51	32.38%	-5.61%	-1.68%	-7.21%	-4.83%	0.06%	61	33.28%	-7.60%
sc_web_browsing_1280x…8bit_rgb.rgb	12.05%	51	13.33%	-1.06%	-0.39%	-1.58%	-1.01%	-1.86%	61	13.55%	-2.21%
average							-1.67%	-1.27%			-3.78%
sc_console_1920x1080_60_8bit_444.yuv	2.16%	117	2.61%	-0.42%	0.78%	0.69%	0.35%	-0.40%	YCgCo	2.16%	0.00%
sc_desktop_1920x1080_60_8bit_444.yuv	1.01%	117	2.46%	-1.12%	0.03%	-0.01%	-0.37%	-1.18%	117	2.46%	-0.37%
sc_flyingGraphics_1920x…8bit_444.yuv	6.59%	117	7.80%	-1.52%	0.01%	0.10%	-0.47%	-1.21%	117	7.80%	-0.47%
sc_map_1280x720_60_8bit_444.yuv	0.10%	114	0.90%	-0.09%	0.01%	-0.02%	-0.03%	-0.13%	117	3.77%	-0.22%
sc_robot_1280x720_30_8bit_444.yuv	0.95%	117	7.31%	-0.36%	0.08%	0.16%	-0.04%	0.56%	114	5.22%	-0.04%
sc_SlideShow_1280x…8bit_444.yuv	0.11%	117	5.37%	-1.29%	0.42%	0.56%	-0.10%	-0.20%	61	0.63%	-0.22%
sc_web_browsing_1280x…8bit_444_r1.yuv	0.15%	117	2.75%	-1.37%	0.05%	-0.27%	-0.53%	-0.95%	117	2.75%	-0.53%
average							-0.17%	-0.50%			-0.26%

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