AHG7: Modification of in-loop colour-space transformation

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Summary

- ❑ In-loop colour-space transformation (L0371/M0411)
  - – Reduces redundancy among Y-Cb-Cr/R-G-B components
  - – Provides good gains on average while coding loss was observed (e.g. 22.6% loss in DucksAndLegs, RA, High-tier, RGB444)

- ❑ Its modification is proposed
  - – To prevent the deterioration of BD-rate
  - – To reduce the run-time of encoder and decoder

- ❑ Simulation results (cross-checked by KDDI: M0407)

Overall gains	High-tier (average of RGB444/YUV444)		
	Y	U	V
AI	-9.8%	-8.1%	-11.5%
RA	-11.2%	-7.4%	-12.7%
LB	-11.1%	-5.8%	-12.7%
Enc Time[%]	103%		
Dec Time[%]	106%		

(only 0.4% loss in DucksAndLegs, RA, High-tier, RGB444)

Block diagram

- "Transformation decision" unit is newly added
- Matrix derivation process is the same as M0411
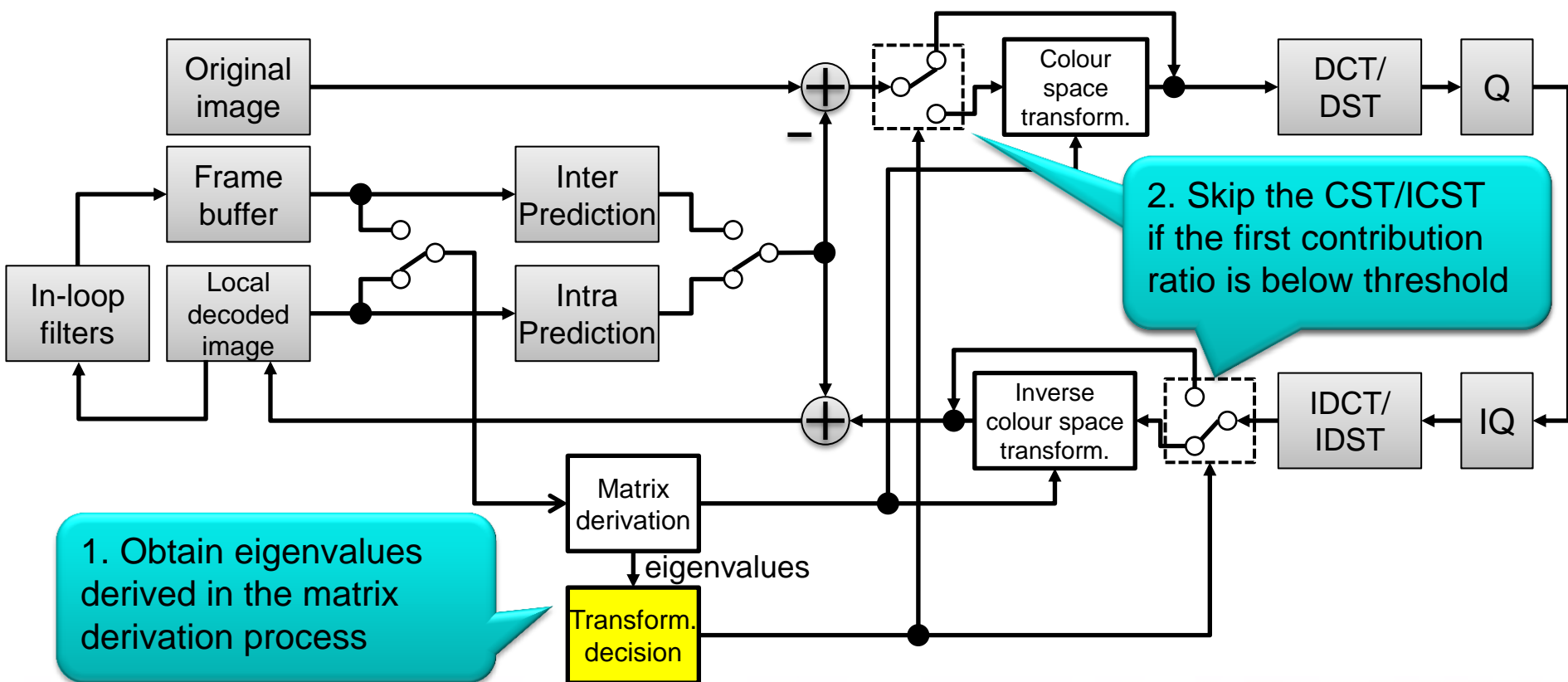
Decoder description (diff. to M0411)

- SumEig := input[0]+input[4]+input[8]
  PrincipalEig := max(input[0],input[4],input[8])
    (input[x]: diagonal elements defined in M0411,
     i.e., *eigenvalues*)
    FirstContributionRatio := PrincipalEig/SumEig
- If FirstContributionRatio < Threshold, then
  - CST is skipped
- Otherwise,
  - CST is applied (the same process as M0411)

- No syntax change: The threshold value is shared between the encoder and decoder in the current implementation

Simulation results

❏ Conditions

- – Proposal was implemented in HM10.0 RExt2.0.
- – Subject to the common test conditions for RExt (L1006)
- – The Threshold is set to 3891÷4096 (= 0.95)

❏ Results (Intra)

	All Intra HE Main-tier			All Intra HE High-tier			All Intra HE Super-High-tier		
	Y	U	V	Y	U	V	Y	U	V
RGB 4:4:4	-21.8%	-15.1%	-20.9%	-16.9%	-11.5%	-16.7%	-12.3%	-8.4%	-12.4%
YCbCr 4:4:4	-1.6%	-7.1%	-6.8%	-1.6%	-4.1%	-5.6%	-1.2%	-2.3%	-4.1%
Overall	-12.4%	-11.4%	-14.3%	-9.8%	-8.1%	-11.5%	-7.1%	-5.6%	-8.5%
	-12.1%	-11.8%	-14.5%	-9.9%	-8.2%	-11.6%	-7.4%	-5.7%	-8.7%
Enc Time[%]	103%			103%			102%		
Dec Time[%]	107%			105%			103%		

Simulation results (Inter)

	Random Access HE Main-tier			Random Access HE High-tier		
	Y	U	V	Y	U	V
RGB 4:4:4	-24.4%	-13.4%	-20.7%	-19.8%	-7.9%	-17.1%
YCbCr 4:4:4	-1.2%	-10.0%	-8.1%	-1.3%	-6.9%	-7.6%
Overall	-13.6%	-11.8%	-14.8%	-11.2%	-7.4%	-12.7%
	-13.2%	-13.6%	-13.8%	-13.0%	-9.6%	-13.9%
Enc Time[%]	104%			104%		
Dec Time[%]	105%			106%		

	Low delay B HE Main-tier			Low delay B HE High-tier		
	Y	U	V	Y	U	V
RGB 4:4:4	-25.2%	-10.3%	-19.7%	-19.4%	-5.3%	-16.5%
YCbCr 4:4:4	-1.5%	-10.1%	-9.1%	-1.7%	-6.3%	-8.3%
Overall	-14.2%	-10.2%	-14.8%	-11.1%	-5.8%	-12.7%
	-13.3%	-7.3%	-12.4%	-12.9%	-6.2%	-12.9%
Enc Time[%]	104%			103%		
Dec Time[%]	108%			108%		

Detailed comparison (AI, RGB4:4:4)

BD-rate deterioration was alleviated

Proposal

	All Intra HE Main-tier			All Intra HE High-tier			All Intra HE Super-High-tier		
	Y	U	V	Y	U	V	Y	U	V
Traffic_2560x1600_30_12bit_444_crop.rgb	-20.7%	-9.1%	-22.1%	-14.2%	-5.5%	-16.0%	-9.9%	-3.7%	-11.2%
Kimono1_1920x1080_24_10bit_444.rgb	-14.7%	-4.4%	-13.3%	-4.4%	-2.1%	-3.9%	-1.0%	-0.3%	-1.1%
EBULupoCandlelight_1920x1080_50_10bit_444.rgb	-47.3%	-36.0%	-46.0%	-44.4%	-26.3%	-43.8%	-30.4%	-18.7%	-31.2%
EBURainFruits_1920x1080_50_10bit_444.rgb	-47.8%	-39.7%	-47.4%	-45.0%	-35.2%	-44.0%	-38.9%	-27.6%	-37.9%
VenueVu_1920x1080_30_8bit_444.rgb	-20.3%	-18.4%	-18.1%	-18.8%	-17.2%	-16.7%	-15.5%	-15.3%	-14.5%
DucksAndLegs_1920x1080_30_10bit_444.rgb	-2.5%	-1.6%	-2.5%	-0.3%	0.0%	-0.4%	0.4%	0.4%	0.4%
OldTownCross_1920x1080_50_10bit_444.rgb	-13.0%	-7.5%	-9.9%	-4.4%	-3.8%	-4.8%	-1.6%	-1.4%	-1.7%
ParkScene_1920x1080_24_10bit_444.rgb	-8.0%	-4.1%	-7.4%	-3.7%	-2.0%	-3.9%	-1.5%	-0.9%	-1.8%
Overall	-21.8%	-15.1%	-20.9%	-16.9%	-11.5%	-16.7%	-12.3%	-8.4%	-12.4%
Enc Time[%]	102%			102%			101%		
Dec Time[%]	104%			102%			100%		

Processing time reduced

M0411

	All Intra HE Main-tier			All Intra HE High-tier			All Intra HE Super-High-tier		
	Y	U	V	Y	U	V	Y	U	V
Traffic_2560x1600_30_12bit_444_crop.rgb	-31.1%	-15.8%	-34.3%	-24.4%	-11.2%	-28.3%	-19.4%	-8.5%	-22.2%
Kimono1_1920x1080_24_10bit_444.rgb	-24.2%	-5.1%	-23.2%	-8.7%	1.4%	-7.5%	-2.5%	4.2%	-1.2%
EBULupoCandlelight_1920x1080_50_10bit_444.rgb	-51.3%	-39.3%	-50.1%	-49.0%	-28.3%	-48.1%	-39.5%	-22.0%	-39.0%
EBURainFruits_1920x1080_50_10bit_444.rgb	-51.2%	-43.2%	-50.8%	-49.0%	-38.6%	-47.8%	-43.4%	-30.5%	-42.0%
VenueVu_1920x1080_30_8bit_444.rgb	-30.3%	-28.4%	-27.4%	-27.7%	-26.2%	-25.0%	-22.5%	-23.0%	-21.5%
DucksAndLegs_1920x1080_30_10bit_444.rgb	-1.9%	-1.4%	-3.7%	9.2%	5.2%	8.3%	17.8%	13.0%	18.7%
OldTownCross_1920x1080_50_10bit_444.rgb	-21.2%	-10.7%	-13.6%	-10.2%	-7.3%	-6.5%	-4.4%	-4.1%	-2.9%
ParkScene_1920x1080_24_10bit_444.rgb	-19.5%	-9.9%	-19.6%	-10.9%	-4.9%	-11.5%	-5.2%	-2.3%	-5.6%
Overall	-28.8%	-19.2%	-27.8%	-21.3%	-13.7%	-20.8%	-14.9%	-9.2%	-14.5%
Enc Time[%]	109%			109%			108%		
Dec Time[%]	104%			104%			103%		

Detailed comparison (RA, RGB4:4:4)

Proposal

	Random Access HE Main-tier			Random Access HE High-tier		
	Y	U	V	Y	U	V
Traffic_2560x1600_30_12bit_444_crop.rgb	-22.3%	-4.1%	-21.5%	-15.3%	0.8%	-15.5%
Kimono1_1920x1080_24_10bit_444.rgb	-21.0%	-7.5%	-18.1%	-11.8%	-1.0%	-8.1%
EBULupoCandlelight_1920x1080_50_10bit_444.rgb	-46.6%	-38.2%	-44.1%	-51.9%	-18.3%	-47.5%
EBURainFruits_1920x1080_50_10bit_444.rgb	-46.0%	-34.5%	-44.6%	-47.1%	-30.4%	-45.1%
VenueVu_1920x1080_30_8bit_444.rgb	-19.1%	-15.7%	-14.8%	-19.3%	-15.8%	-14.9%
DucksAndLegs_1920x1080_30_10bit_444.rgb	-7.0%	-1.1%	-5.2%	-1.4%	0.4%	-1.0%
OldTownCross_1920x1080_50_10bit_444.rgb	-23.6%	-1.5%	-10.2%	-5.9%	1.7%	-0.9%
ParkScene_1920x1080_24_10bit_444.rgb	-9.6%	-4.2%	-7.0%	-6.0%	-0.8%	-3.9%
Overall	-24.4%	-13.4%	-20.7%	-19.8%	-7.9%	-17.1%
Enc Time[%]	104%			103%		
Dec Time[%]	105%			105%		

22.2% improvement

M0411

	Random Access HE Main-tier			Random Access HE High-tier		
	Y	U	V	Y	U	V
Traffic_2560x1600_30_12bit_444_crop.rgb	-34.9%	-4.8%	-35.2%	-27.7%	4.6%	-29.2%
Kimono1_1920x1080_24_10bit_444.rgb	-33.7%	-8.7%	-30.9%	-22.0%	9.6%	-17.5%
EBULupoCandlelight_1920x1080_50_10bit_444.rgb	-50.2%	-42.2%	-48.0%	-56.4%	-20.0%	-52.1%
EBURainFruits_1920x1080_50_10bit_444.rgb	-48.3%	-37.0%	-47.0%	-50.0%	-32.8%	-47.8%
VenueVu_1920x1080_30_8bit_444.rgb	-27.1%	-23.1%	-21.9%	-27.4%	-23.1%	-21.9%
DucksAndLegs_1920x1080_30_10bit_444.rgb	-16.4%	14.4%	-13.0%	0.4%	22.6%	3.8%
OldTownCross_1920x1080_50_10bit_444.rgb	-37.9%	-0.8%	-16.3%	-15.6%	5.8%	0.1%
ParkScene_1920x1080_24_10bit_444.rgb	-26.5%	-7.5%	-20.4%	-20.9%	8.6%	-13.6%
Overall	-34.4%	-13.7%	-29.1%	-27.4%	-3.1%	-22.3%
Enc Time[%]	106%			106%		
Dec Time[%]	105%			107%		

Detailed comparison (LB, RGB4:4:4)

Proposal

	Low delay B HE Main-tier			Low delay B HE High-tier		
	Y	U	V	Y	U	V
Traffic_2560x1600_30_12bit_444_crop.rgb	-23.3%	-1.5%	-22.5%	-15.7%	2.6%	-16.3%
Kimono1_1920x1080_24_10bit_444.rgb	-24.5%	-6.3%	-19.1%	-12.5%	-1.0%	-8.2%
EBULupoCandlelight_1920x1080_50_10bit_444.rgb	-46.1%	-28.1%	-41.6%	-54.6%	-8.7%	-48.3%
EBURainFruits_1920x1080_50_10bit_444.rgb	-37.1%	-27.9%	-39.6%	-38.3%	-24.0%	-41.0%
VenueVu_1920x1080_30_8bit_444.rgb	-17.7%	-13.0%	-12.8%	-17.3%	-13.3%	-13.0%
DucksAndLegs_1920x1080_30_10bit_444.rgb	-9.4%	-1.0%	-6.2%	-1.8%	0.4%	-1.1%
OldTownCross_1920x1080_50_10bit_444.rgb	-32.0%	-1.5%	-9.7%	-8.2%	1.8%	-1.2%
ParkScene_1920x1080_24_10bit_444.rgb	-11.8%	-3.1%	-6.2%	-6.7%	-0.4%	-3.3%
Overall	-25.2%	-10.3%	-19.7%	-19.4%	-5.3%	-16.5%
Enc Time[%]	103%			103%		
Dec Time[%]	107%			107%		

> Average coding gain of U was improved

M0411

	Low delay B HE Main-tier			Low delay B HE High-tier		
	Y	U	V	Y	U	V
Traffic_2560x1600_30_12bit_444_crop.rgb	-34.3%	1.2%	-35.8%	-27.0%	9.4%	-30.5%
Kimono1_1920x1080_24_10bit_444.rgb	-36.4%	-3.4%	-29.6%	-24.5%	12.0%	-15.3%
EBULupoCandlelight_1920x1080_50_10bit_444.rgb	-49.0%	-30.9%	-44.7%	-59.0%	-7.5%	-52.8%
EBURainFruits_1920x1080_50_10bit_444.rgb	-38.3%	-29.6%	-41.3%	-40.4%	-25.6%	-43.3%
VenueVu_1920x1080_30_8bit_444.rgb	-26.1%	-20.5%	-20.1%	-25.4%	-20.9%	-20.3%
DucksAndLegs_1920x1080_30_10bit_444.rgb	-21.4%	16.5%	-13.7%	-0.4%	18.9%	2.8%
OldTownCross_1920x1080_50_10bit_444.rgb	-47.4%	0.7%	-14.2%	-18.9%	5.1%	1.4%
ParkScene_1920x1080_24_10bit_444.rgb	-31.9%	-1.5%	-16.3%	-24.6%	10.3%	-10.3%
Overall	-35.6%	-8.4%	-27.0%	-27.5%	0.2%	-21.0%
Enc Time[%]	105%			105%		
Dec Time[%]	106%			107%		

Conclusion

❑ Modified in-loop colour-space transformation

  – CST is adaptively applied using an eigenvalue

❑ Compared to M0411:

  – Deterioration of BD-rate was alleviated

  – Encoding and decoding run-times were reduced

Overall gains	High-tier (average of RGB444/YUV444)		
	Y	U	V
AI	-9.8%	-8.1%	-11.5%
RA	-11.2%	-7.4%	-12.7%
LB	-11.1%	-5.8%	-12.7%
Enc Time[%]	103%		
Dec Time[%]	106%		

❑ Suggestion:

  – Investigate this modification in RCE1

  – Adopt "M0411+M0072" to HEVC ver.2

Thank you, questions?

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