G-PCC:
Significant coefficient coding

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Summary

Significant coefficient flags

- Current design:
  - Zero-run-length coded using truncated unary code
- Proposed design:
  - Bi-state run-length coded using sub-exponential codes

Summary

Significant coefficient sign

- Current design:
  - Map signed magnitude → unsigned = $2|x| + \text{sgn}(x) - [x \neq 0]$
- Proposed design:
  - Code conditional sign bit (bypass) independently of magnitude

Detail: significant coefficient flags

Current design

p0 = 0.9

Coeff > 0: 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0

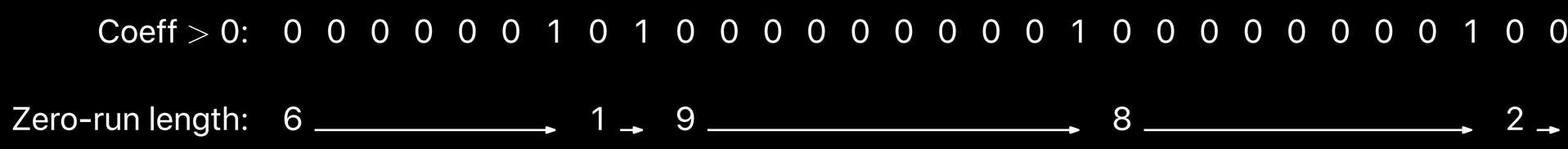
p0 = 0.2

Coeff > 0: 1 1 1 1 1 0 1 1 0 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1

Detail: significant coefficient flags

Current design

p0 = 0.9



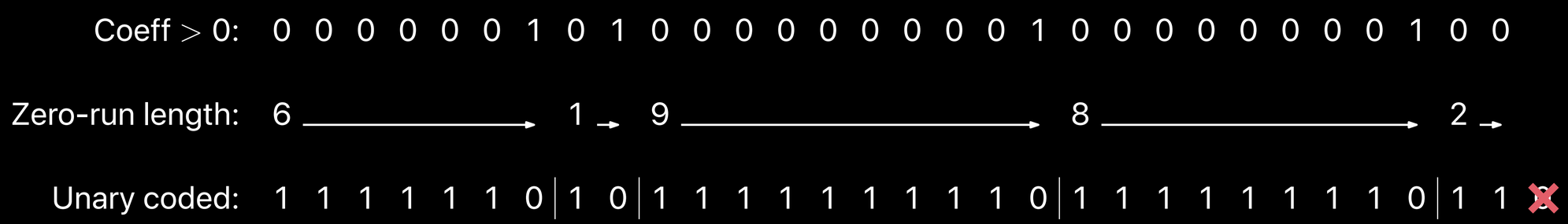
p0 = 0.2



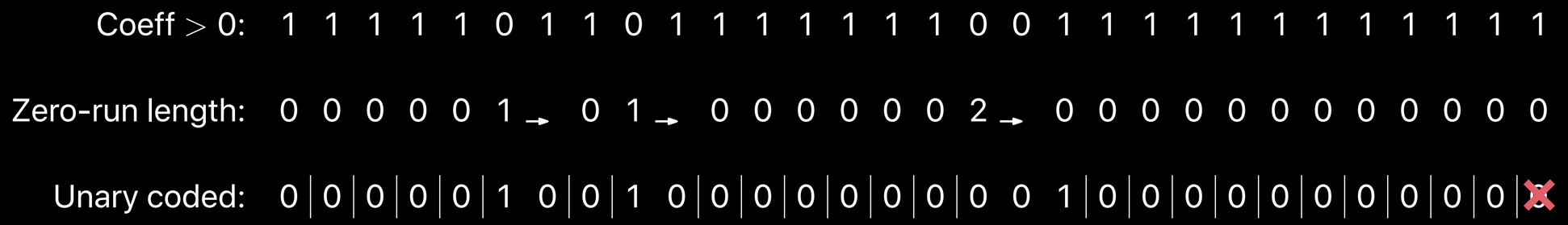
Detail: significant coefficient flags

Current design

p0 = 0.9



p0 = 0.2



Detail: significant coefficient flags

Proposed design

p0 = 0.9

Coeff > 0: 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0

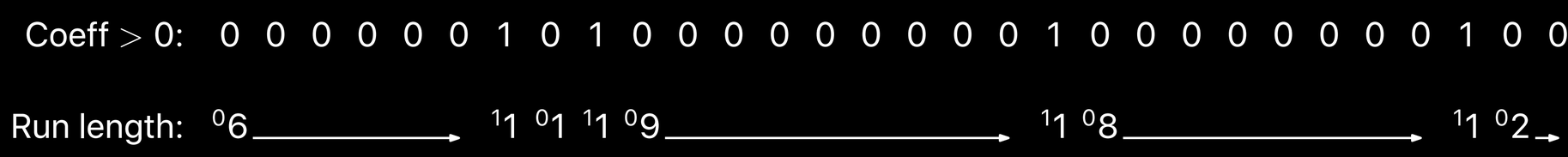
p0 = 0.2

Coeff > 0: 1 1 1 1 1 0 1 1 0 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1

Detail: significant coefficient flags

Proposed design

p0 = 0.9



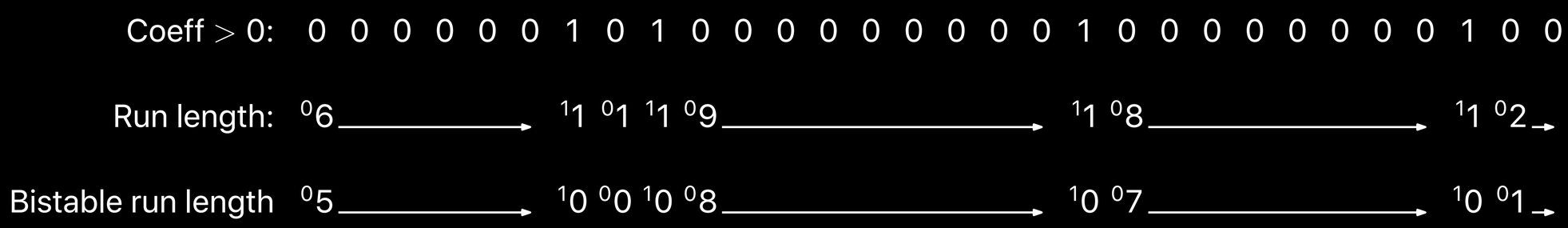
p0 = 0.2



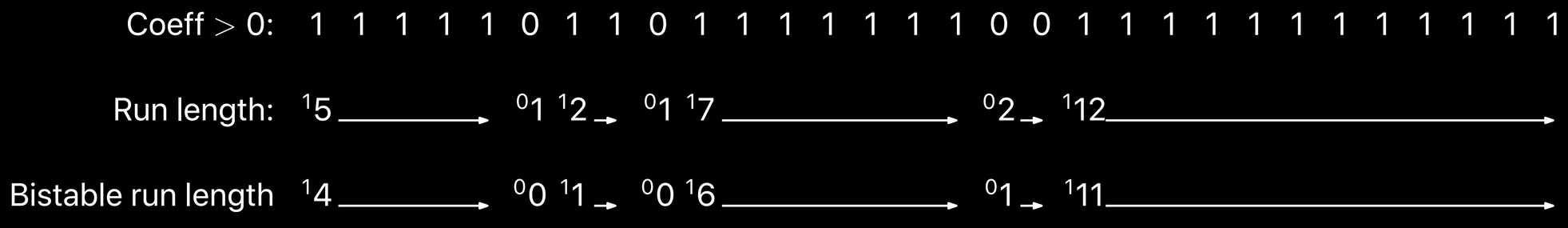
Detail: significant coefficient flags

Proposed design

p0 = 0.9



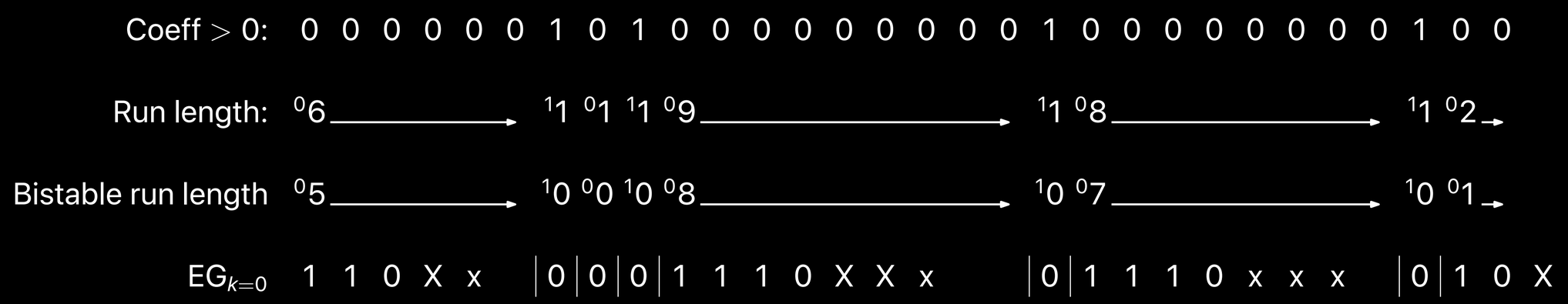
p0 = 0.2



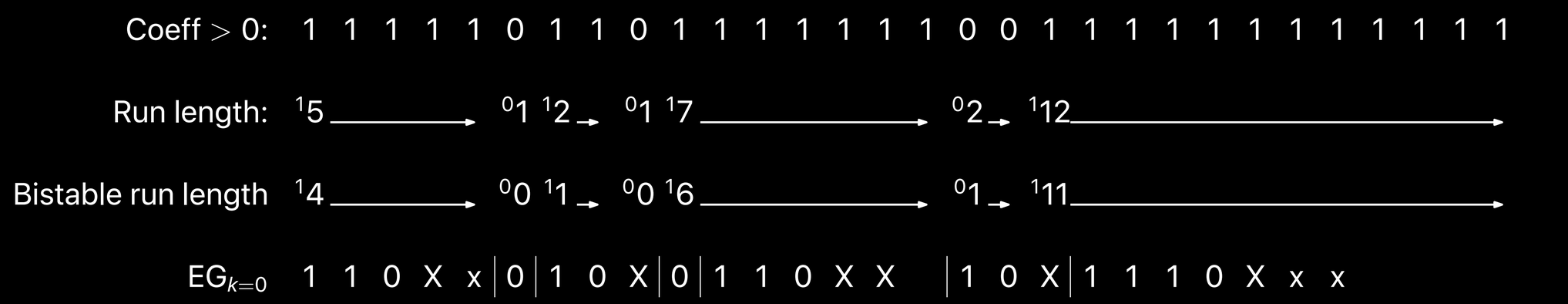
Detail: significant coefficient flags

Proposed design

p0 = 0.9



p0 = 0.2



Detail: significant coefficient flags

Bin reductions, longdress_vox10_1300

Configuration	AecBin reduction	Bypass Bins
lod/lossless-geom-lossless-attrs	89%	38%
lod/lossless-geom-lossy-attrs/r01	97%	34%
lod/lossless-geom-lossy-attrs/r02	95%	34%
lod/lossless-geom-lossy-attrs/r03	90%	34%
lod/lossless-geom-lossy-attrs/r04	81%	34%
lod/lossless-geom-lossy-attrs/r05	67%	33%
lod/lossless-geom-lossy-attrs/r06	53%	32%
lod/lossless-geom-nearlossless-attrs/r01	63%	34%
lod/lossless-geom-nearlossless-attrs/r02	50%	32%
lod/lossless-geom-nearlossless-attrs/r03	40%	31%
lod/lossless-geom-nearlossless-attrs/r04	46%	31%
lod/lossless-geom-nearlossless-attrs/r05	67%	34%
raht/lossless-geom-lossy-attrs/r01	99%	36%
raht/lossless-geom-lossy-attrs/r02	97%	36%
raht/lossless-geom-lossy-attrs/r03	92%	35%
raht/lossless-geom-lossy-attrs/r04	82%	34%
raht/lossless-geom-lossy-attrs/r05	67%	33%
raht/lossless-geom-lossy-attrs/r06	52%	32%

Detail: significant coefficient flags

Example (Decoder)

```
// NB: initial runType is inverted to make loop more readable
runType = 1 ^ decodeRunType();
runLength = 0
for (idx = 0; idx < numPoints; idx++) {
  if (!runLength--) {
    // end of run, decode next run length
    // run type inverts with each run
    runLength = decodeRunLengthMinus1(runType);
    runType = !runType;

    // If starting a run of zeros, process here and jump to next run
    if (runType == 0) {
      fill(coeff[i], runLength + 1, 0);
      idx += runLength;
      runLength = 0;
      continue;
    }
  }
  // NB: coefficient is known not to equal 0 since this isn't a run of zeros.
  coeff[idx] = decodeCoeff();
}
```

Results

Significant coefficient flags vs v9.0 CTC, LoD

		BPP Ratio [%]			BD-Rate [Δ%]					maxrssk [%]		runtime [%]	
Condition	Class	Geometry	Colour	Reflectance	D1	D2	Y	Cb	Cr	R	Enc	Dec	Enc	Dec
C1_ai	cat1-A				0.0	0.0	-2.5	-4.5	-5.1		101	100	99	99
C1_ai	cat1-B				0.0	0.0	-0.3	-1.2	-1.8		100	100	99	97
C1_ai	cat3-fused				0.0	0.0	0.1	0.1	0.1	0.3	100	100	99	99
C1_ai	cat3-frame				0.0	0.0				-0.6	100	100	104	104
C1_ai	overall				0.0	0.0	-1.3	-2.6	-3.2	-0.3	100	100	100	99
C2_ai	cat1-A				0.0	0.0	-0.4	-0.6	-0.7		100	100	101	94
C2_ai	cat1-B				0.0	0.0	-0.1	-0.6	-1.0		100	100	101	100
C2_ai	cat3-fused				0.0	0.0	0.2	0.2	0.2	0.6	101	100	98	99
C2_ai	cat3-frame				0.0	0.0				0.6	100	100	99	96
C2_ai	overall				0.0	0.0	-0.2	-0.6	-0.8	0.6	100	100	101	97
CW_ai	cat1-A	100.0	100.1								100	100	96	98
CW_ai	cat1-B	100.0	100.0								100	100	101	104
CW_ai	cat3-fused	100.0	100.0	100.2							100	100	98	81
CW_ai	cat3-frame	100.0		100.2							100	100	98	97
CW_ai	overall	100.0	100.1	100.2							100	100	99	100
CY_ai	cat1-A				0.0	0.0	0.7	0.7	0.7		100	100	101	97
CY_ai	cat1-B				0.0	0.0	0.6	0.6	0.6		100	100	99	103
CY_ai	cat3-fused				0.0	0.0	0.4	0.4	0.4	1.1	100	100	97	94
CY_ai	cat3-frame				0.0	0.0				0.5	100	100	102	100
CY_ai	overall				0.0	0.0	0.6	0.6	0.6	0.7	100	100	100	100

NOTE --- Condition CY metrics reported using Hausdorff PSNR.

Results

Significant coefficient flags vs v9.0 CTC, RAHT

					BPP Ratio [%]			BD-Rate [Δ%]			maxrssk [%]		runtime [%]	
Condition	Class	Geometry	Colour	Reflectance	D1	D2	Y	Cb	Cr	R	Enc	Dec	Enc	Dec
C1_ai	cat1-A				0.0	0.0	-4.4	-5.4	-5.9		101	101	97	99
C1_ai	cat1-B				0.0	0.0	-1.2	-1.8	-2.0		100	100	98	99
C1_ai	cat3-fused				0.0	0.0	0.1	0.2	0.2	-0.1	100	100	102	99
C1_ai	cat3-frame				0.0	0.0				-1.0	100	100	100	100
C1_ai	overall				0.0	0.0	-2.6	-3.3	-3.6	-0.7	100	100	98	99
C2_ai	cat1-A				0.0	0.0	-1.2	-1.4	-1.3		100	101	102	95
C2_ai	cat1-B				0.0	0.0	-0.8	-1.3	-1.5		100	100	101	97
C2_ai	cat3-fused				0.0	0.0	0.2	0.2	0.3	0.4	100	100	98	96
C2_ai	cat3-frame				0.0	0.0				-0.1	100	100	100	100
C2_ai	overall				0.0	0.0	-0.9	-1.3	-1.3	0.1	100	100	101	97

Results

Significant coefficient sign vs v9.0 CTC, LoD

		BPP Ratio [%]			BD-Rate [Δ%]					maxrssk [%]		runtime [%]	
Condition	Class	Geometry	Colour	Reflectance	D1	D2	Y	Cb	Cr	R	Enc	Dec	Enc	Dec
C1_ai	cat1-A				0.0	0.0	-0.7	-0.6	-0.6		100	100	97	99
C1_ai	cat1-B				0.0	0.0	-0.5	-0.5	-0.5		100	100	96	96
C1_ai	cat3-fused				0.0	0.0	-0.5	-0.6	-0.6	-0.3	100	100	98	98
C1_ai	cat3-frame				0.0	0.0				-0.5	100	100	96	96
C1_ai	overall				0.0	0.0	-0.6	-0.5	-0.5	-0.4	100	100	97	97
C2_ai	cat1-A				0.0	0.0	-0.8	-0.8	-0.8		100	100	100	93
C2_ai	cat1-B				0.0	0.0	-0.5	-0.5	-0.5		100	100	99	98
C2_ai	cat3-fused				0.0	0.0	-0.3	-0.5	-0.4	-0.2	100	100	101	97
C2_ai	cat3-frame				0.0	0.0				-0.5	100	100	97	95
C2_ai	overall				0.0	0.0	-0.6	-0.6	-0.6	-0.4	100	100	99	96
CW_ai	cat1-A	100.0	98.1								100	100	94	97
CW_ai	cat1-B	100.0	97.8								100	100	96	97
CW_ai	cat3-fused	100.0	98.0	98.1							100	100	99	89
CW_ai	cat3-frame	100.0		98.0							100	100	104	104
CW_ai	overall	100.0	97.9	98.1							100	100	96	97
CY_ai	cat1-A				0.0	0.0	0.1	0.1	0.1		100	100	100	99
CY_ai	cat1-B				0.0	0.0	-0.3	-0.3	-0.3		100	100	95	97
CY_ai	cat3-fused				0.0	0.0	-1.1	-1.1	-1.1	-0.5	100	100	98	96
CY_ai	cat3-frame				0.0	0.0				-0.5	100	100	96	96
CY_ai	overall				0.0	0.0	-0.2	-0.2	-0.2	-0.5	100	100	97	97

NOTE --- Condition CY metrics reported using Hausdorff PSNR.

Results

Significant coefficient sign vs v9.0 CTC, RAHT

				BPP Ratio [%]			BD-Rate [Δ%]			maxrssk [%]		runtime [%]	
Condition	Class	Geometry	Colour	Reflectance	D1	D2	Y	Cb	Cr	R	Enc	Dec	Enc	Dec
C1_ai	cat1-A				0.0	0.0	-0.6	-0.6	-0.6		100	101	97	98
C1_ai	cat1-B				0.0	0.0	-0.5	-0.5	-0.5		100	100	96	97
C1_ai	cat3-fused				0.0	0.0	-0.5	-0.6	-0.6	-0.4	100	100	97	94
C1_ai	cat3-frame				0.0	0.0				-0.5	100	100	97	98
C1_ai	overall				0.0	0.0	-0.5	-0.5	-0.5	-0.5	100	100	97	97
C2_ai	cat1-A				0.0	0.0	-0.9	-1.0	-0.9		100	101	103	97
C2_ai	cat1-B				0.0	0.0	-0.5	-0.4	-0.3		100	100	97	98
C2_ai	cat3-fused				0.0	0.0	-0.5	-0.6	-0.6	-0.3	100	100	95	98
C2_ai	cat3-frame				0.0	0.0				-0.6	100	100	93	93
C2_ai	overall				0.0	0.0	-0.7	-0.7	-0.6	-0.5	100	100	98	97

Detail: Coefficient sign coding

```
-PCCResidualsEncoder::encode(uint32_t value0, uint32_t value1, uint32_t value2)
+PCCResidualsEncoder::encode(int32_t value0, int32_t value1, int32_t value2)

-  if (value0 == value1 && value0 == value2) {
-    value0--;
-    value1--;
-    value2--;
-  }
-
-  int b0 = (value0 == 0);
-  int b1 = (value0 <= 1);
-  int b2 = (value1 == 0);
-  int b3 = (value1 <= 1);
-  encodeSymbol(value0, 0, 0, 0);
-  encodeSymbol(value1, 1 + b0, 1 + b1, 1);
-  encodeSymbol(value2, 3 + (b0 << 1) + b2, 3 + (b1 << 1) + b3, 1);
+  int mag0 = abs(value0);
+  int mag1 = abs(value1);
+  int mag2 = abs(value2);
+//  NB: not exploiting impossibility of mag0=mag1=mag2=0
+
+  int b0 = (mag0 == 0);
+  int b1 = (mag0 <= 1);
+  int b2 = (mag1 == 0);
+  int b3 = (mag1 <= 1);
+  encodeSymbol(mag0, 0, 0, 0);
+  encodeSymbol(mag1, 1 + b0, 1 + b1, 1);
+  encodeSymbol(mag2, 3 + (b0 << 1) + b2, 3 + (b1 << 1) + b3, 1);
+
+  if (mag0)
+    arithmeticEncoder.encode(value0 < 0, binaryModel0);
+  if (mag1)
+    arithmeticEncoder.encode(value1 < 0, binaryModel0);
+  if (mag2)
+    arithmeticEncoder.encode(value2 < 0, binaryModel0);
```

```
-PCCResidualsDecoder::decode(uint32_t value[3])
+PCCResidualsDecoder::decode(int32_t value[3])
 {
   value[0] = decodeSymbol(0, 0, 0);
   int b0 = value[0] == 0;
   int b1 = value[0] <= 1;
   value[1] = decodeSymbol(1 + b0, 1 + b1, 1);
   int b2 = value[1] == 0;
   int b3 = value[1] <= 1;
   value[2] = decodeSymbol(3 + (b0 << 1) + b2, 3 + (b1 << 1) + b3, 1);

-  int d = (value[0] == value[1] && value[0] == value[2]);
-  for (int k = 0; k < 3; k++) {
-    value[k] += d;
-  }
+  if (value[0] && arithmeticDecoder.decode(binaryModel0))
+    value[0] = -value[0];
+  if (value[1] && arithmeticDecoder.decode(binaryModel0))
+    value[1] = -value[1];
+  if (value[2] && arithmeticDecoder.decode(binaryModel0))
+    value[2] = -value[2];
 }
```



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