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ABCD : Arbitrary Bitwise Coefficient for De-Quantization

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TUE-PM-167

Visual Demonstration

Sintel 2-bit ⟶ 8-bit

2-bit Input

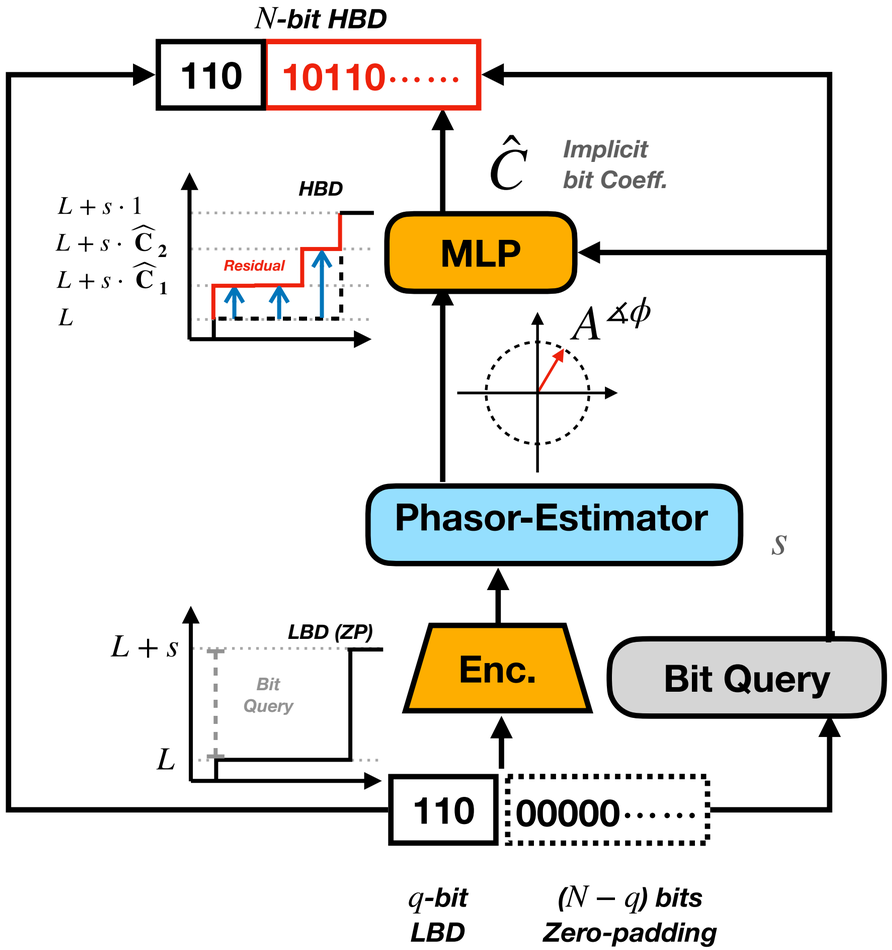
ABCD (Ours)

GT

Blurred Details

False Contour

ABCD



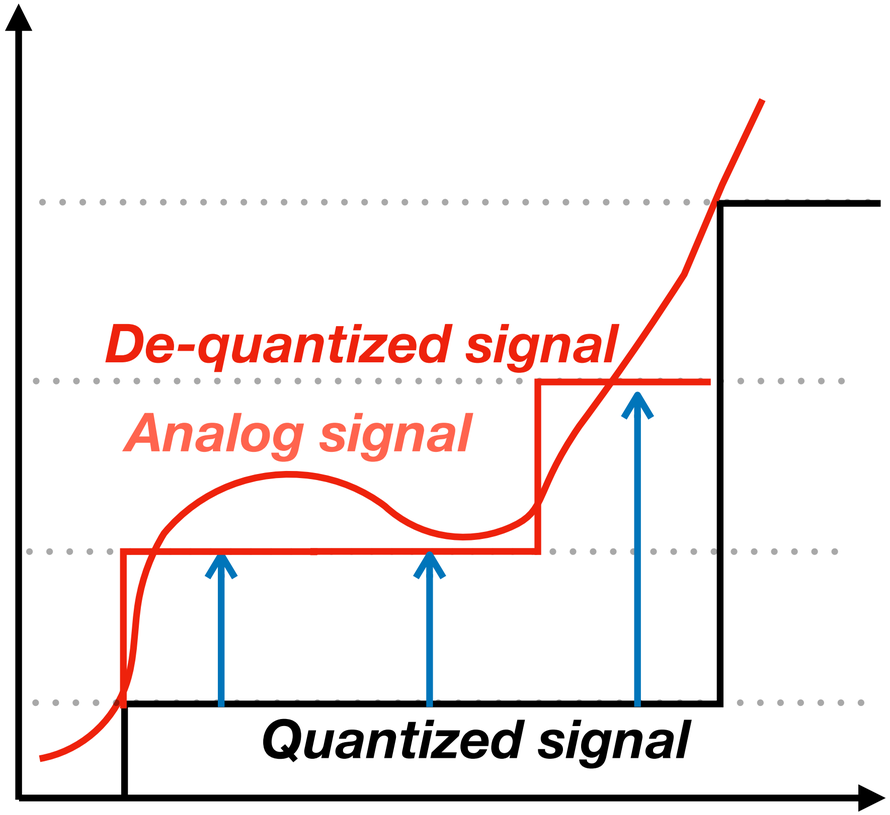
- BDE algorithm using INR
  With Bitwise Coefficients
- Phasor estimator
  To Relieve Spectral bias
- State-of-the-Art Performance
  with Single training

Bit Depth Expansion

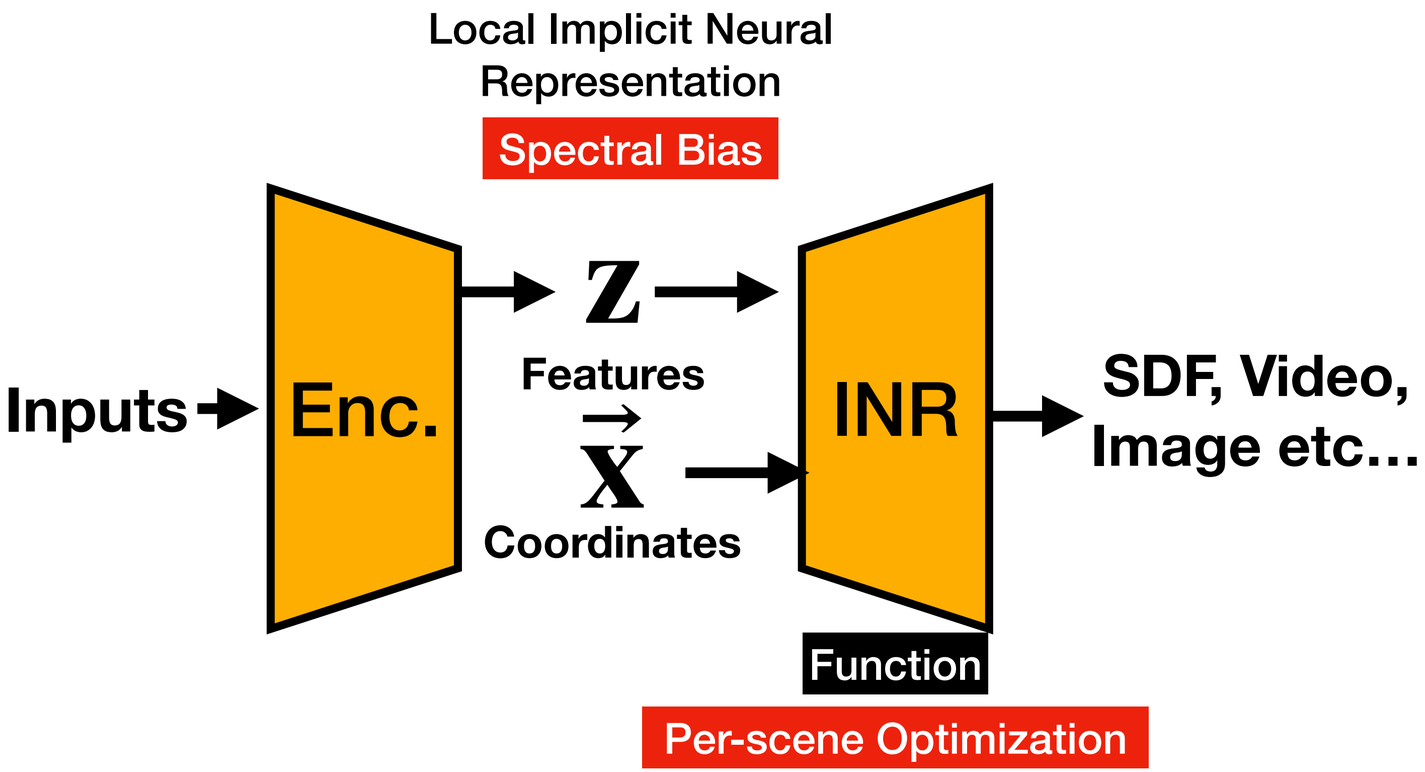
Quantization & De-quantization

High Bit Depth (HBD)

110	100111011



Implicit Neural Representation



- How to define a coordinate and corresponding signal to BDE?
- How to mitigate the spectral bias?

Formulation

Bit-wise Coefficient

$$a = \sum_{i=-\infty}^{\infty} b_i 2^i \qquad (b_i \in \{0,1\})$$

positive real number

$$= \sum_{i=L+1}^{\infty} b_i 2^i + \sum_{j=-\infty}^{L} b_j 2^j \qquad (* \sum_{k=0}^{\infty} a_0 r^k = \frac{a_0}{1-r} \quad (|r| < 1))$$

$$= \sum_{i=L+1}^{\infty} b_i 2^i + C \cdot 2^{L+1}, \qquad C \in [0,1]$$

Formulation

Bit-wise Basis

$\mathbb{F}_2 := (\{0,1\}, \oplus, \cdot)$ ($\oplus$: XOR operation, $\cdot$: multiplication)

$\{0,1\}^N \longrightarrow \exists e_q$ Orthonormal basis

$e_q \sim 2^{N-q}$ (As digital number)

- ex) $e_4 = \boxed{00010000} \sim 2^{8-4}$

Formulation

Image Quantization

$$\mathbf{I_q} = \left\lfloor \frac{\mathbf{I_N}}{2^{N-q}} \right\rfloor 2^{N-q}$$

$$\mathbf{I_N} = \mathbf{I_q} + \mathbf{R}$$

$$= \underbrace{\boxed{b_1 b_2 b_3}}_{\mathbf{I_q}} \underbrace{\boxed{b_4 b_5 b_6 b_7 b_8}}_{\mathbf{R}}$$

Bit-wise Coefficients

$$a = \sum_{i=L+1}^{\infty} b_i 2^i + C \cdot 2^{L+1}$$

Bit-wise basis

$$e_q \sim 2^{N-q}$$

Conclusion

$$\mathbf{I_N} = \underbrace{\sum_{i=N-q}^{N-1} 2^i \cdot \mathbf{B}_i}_{\mathbf{I}_q} + \underbrace{2^{N-q} \cdot \mathbf{C}}_{\mathbf{R}} \rightarrow f_\theta(e_q, \mathbf{z})$$

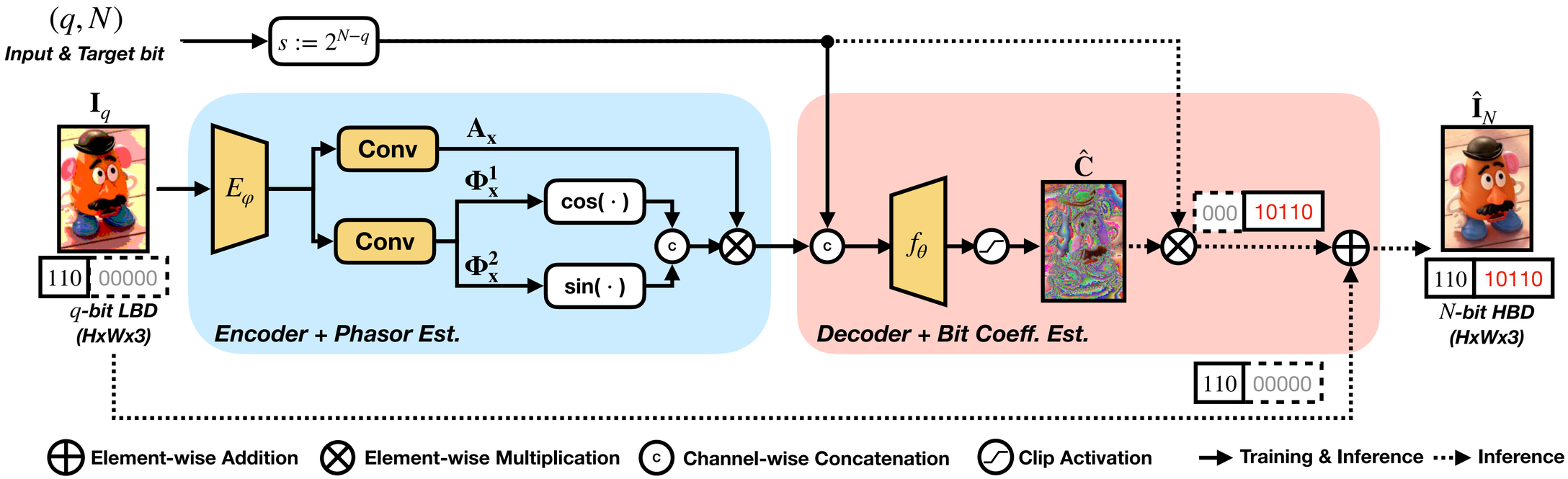
Formulation

Phasor estimator

$$\underbrace{\mathbf{A}_j \odot \begin{bmatrix} \cos(\pi(\mathbf{F_j} \cdot \delta + h_p(\hat{\mathbf{c}})) \\ \sin(\pi(\mathbf{F_j} \cdot \delta + h_p(\hat{\mathbf{c}})) \end{bmatrix}_{\vec{\delta} = \vec{\mathbf{0}}}}_{\text{LTE}} \longrightarrow \underbrace{\begin{bmatrix} \mathbf{A}_\mathbf{x}^1 \\ \mathbf{A}_\mathbf{x}^2 \end{bmatrix} \odot \begin{bmatrix} \cos(\pi\mathbf{\Phi}_\mathbf{x}^1) \\ \sin(\pi\mathbf{\Phi}_\mathbf{x}^2) \end{bmatrix}}_{\text{ABCD}}$$

Lee, Jaewon, and Kyong Hwan Jin. "Local Texture Estimator for Implicit Representation Function." *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*. 2022.

ABCD Structure



- Encoder (E_φ) : EDSR (17') , RDN (18'), SwinIR (21')
- Decoder (f_θ) : 4-Layer Multi-layer perceptron (MLP)

Quantitative comparison

PSNR(dB) / SSIM

Vaild	Sintel						MIT-Adobe FiveK			
Method	4 >> 8	4 >> 12	4 >> 16	6 >> 12	6 >> 16	8 >> 16	3 >> 16	4 >> 16	5 >> 16	6 >> 16
Input(zp)	29.16 0.8864	28.78 0.8844	28.77 0.8843	40.90 0.9858	40.81 0.9857	52.85 0.9990	22.90 0.7381	28.86 0.8769	34.86 0.9556	40.88 0.9871
IPAD	35.86 0.9457	35.78 0.9452	35.76 0.9451	47.66 0.9903	47.62 0.9902	58.62 0.9989	29.86 0.8624	35.74 0.9378	41.18 0.9743	46.43 0.9903
BitNet (0.94M)	39.34 0.9701	39.49 0.9719	39.49 0.9719	49.72 0.9954	49.68 0.9954	57.55 0.9989	33.46 0.9128	39.12 0.9632	44.02 0.9853	48.46 0.9943
BE-CALF (5.18M)	39.91 0.9737	39.98 0.9752	39.98 0.9752	51.14 0.9940	51.14 0.9940	59.51 0.9993	- -	- -	- -	- -
D16 (<15.46M)	41.19 0.9794	41.51 0.9810	41.51 0.9810	53.47 0.9980	53.48 0.9979	63.51 0.9998	34.11 0.9279	39.95 0.9693	44.94 0.9876	49.72 0.9953
RDN-ABCD (Ours) *(11.52M)*	42.31 0.9831	42.84 0.9847	42.84 0.9847	54.07 0.9984	54.10 0.9984	63.75 0.9998	35.14 0.9392	40.94 0.9746	45.68 0.9893	50.08 0.9957
EDSR-ABCD (Ours) *(12.22M)*	42.47 0.9837	43.02 0.9852	43.02 0.9852	54.15 0.9984	54.18 0.9984	63.78 0.9998	35.25 0.9401	41.04 0.9748	45.74 0.9893	50.11 0.9957
SwinIR-ABCD (Ours) *(12.10M)*	42.51 0.9844	43.03 0.9855	43.03 0.9855	54.08 0.9984	54.12 0.9984	63.74 0.9998	35.44 0.9412	41.18 0.9751	45.80 0.9895	50.13 0.9957

Qualitative Comparison

(3-bit→8-bit)

IPAD | BitNet | D16 | ABCD(Ours) | GT

Qualitative Comparison

(3-bit→8-bit)

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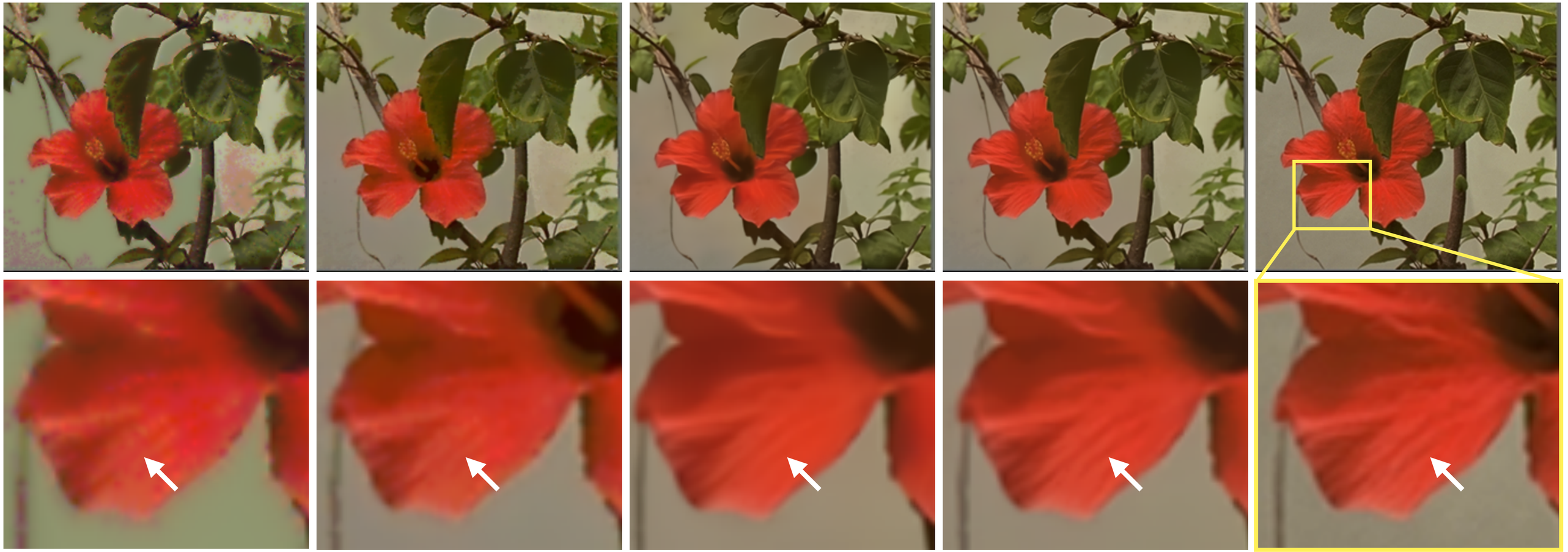

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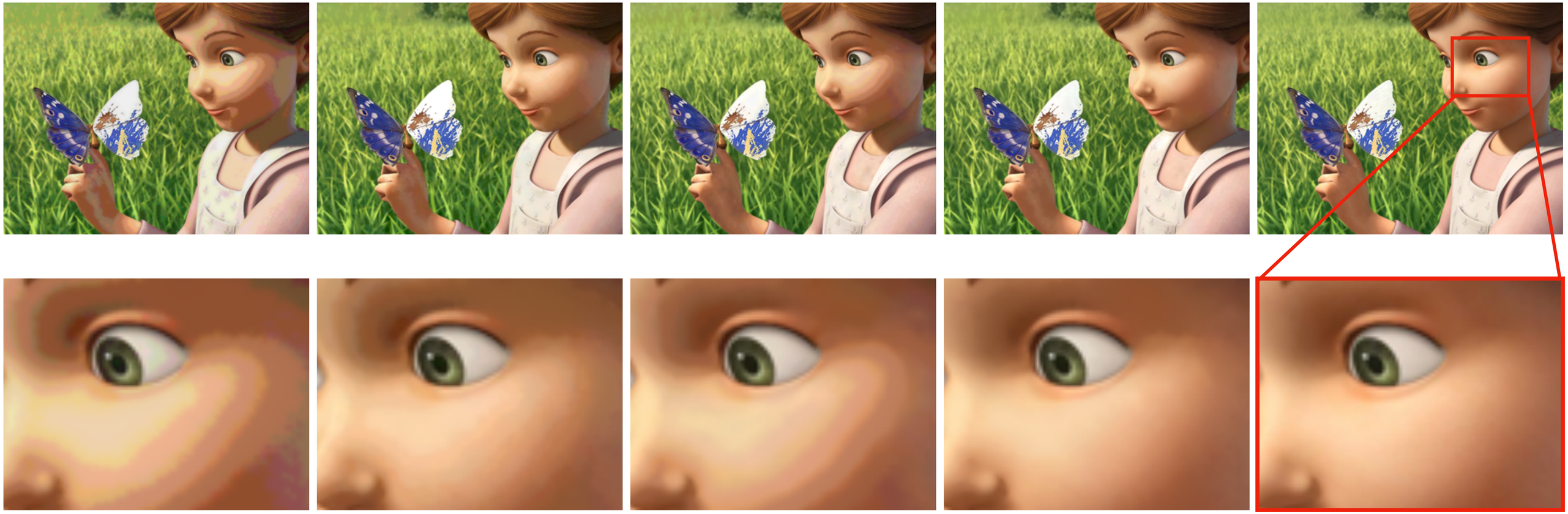

Qualitative Comparison

(3-bit→8-bit)

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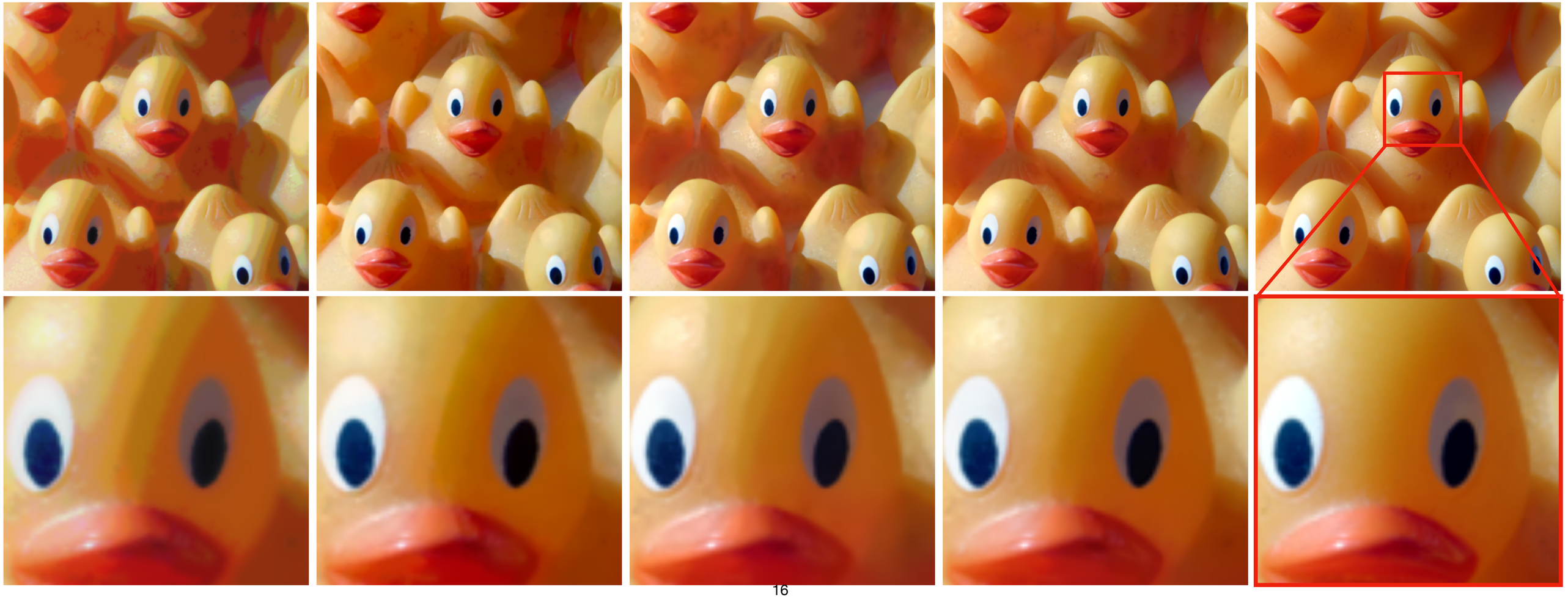


Qualitative Comparison

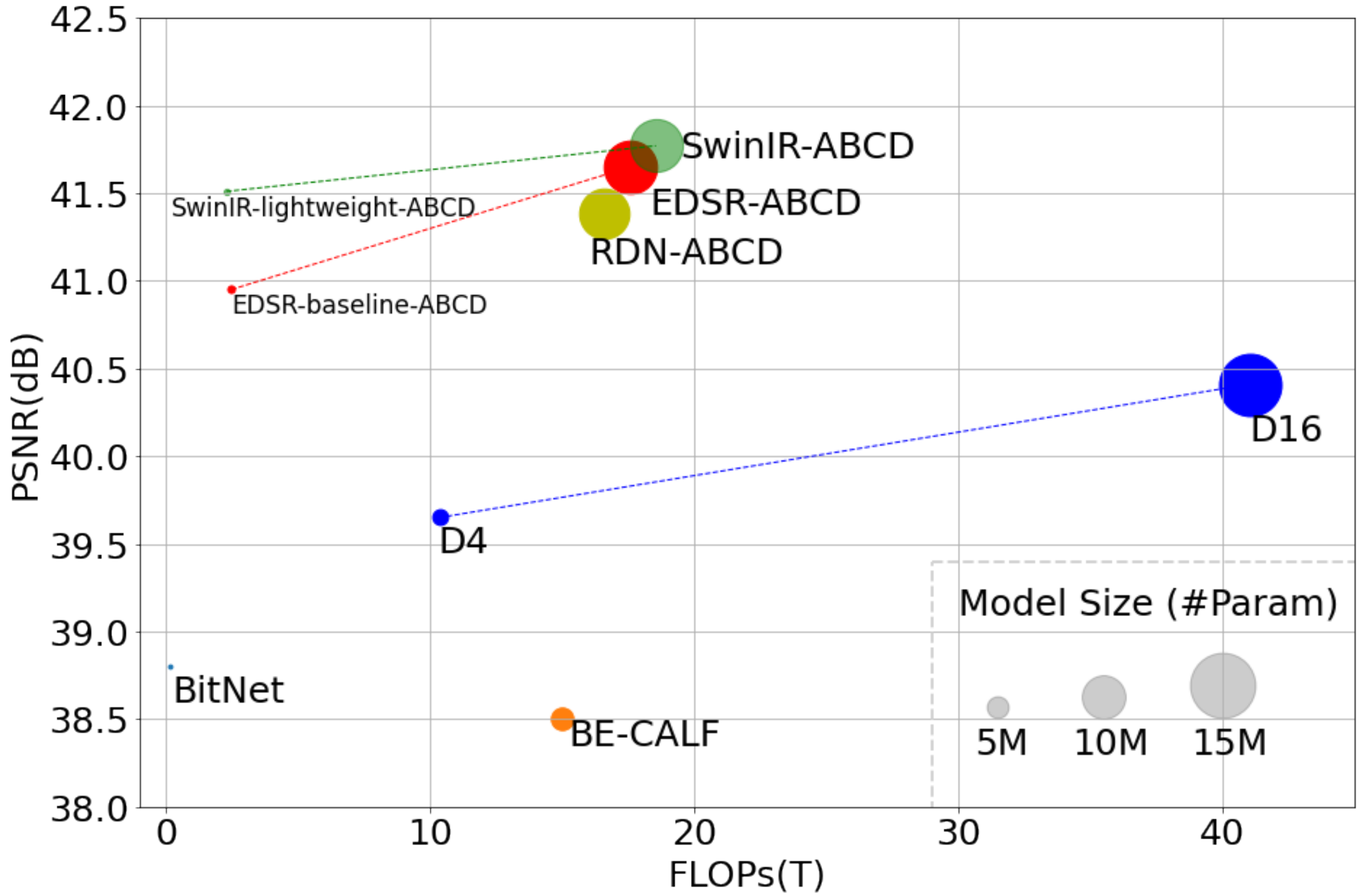
(2-bit→8-bit) : Out-of-distribution

Input	IPAD	BitNet	ABCD(Ours)	GT

- 2-bit input is out-of-distribution cases for all methods

FLOPs and Memories

FLOPs vs PSNR



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Paper Code DEMO:)