ABCD : Arbitrary Bitwise Coefficient for De-quantization

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Paper Code Demo ☺

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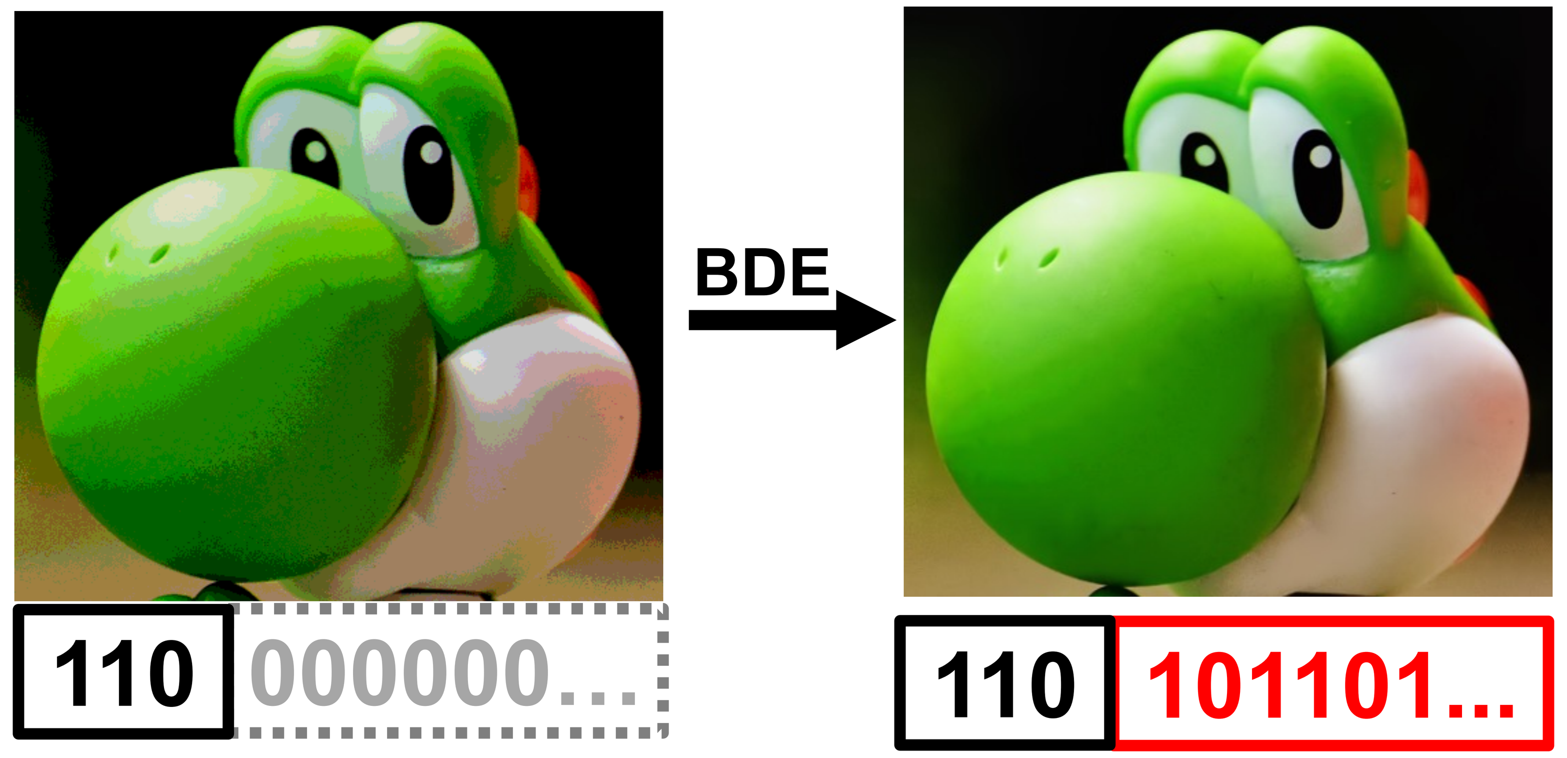
Introduction

Bit Depth Expansion (BDE)

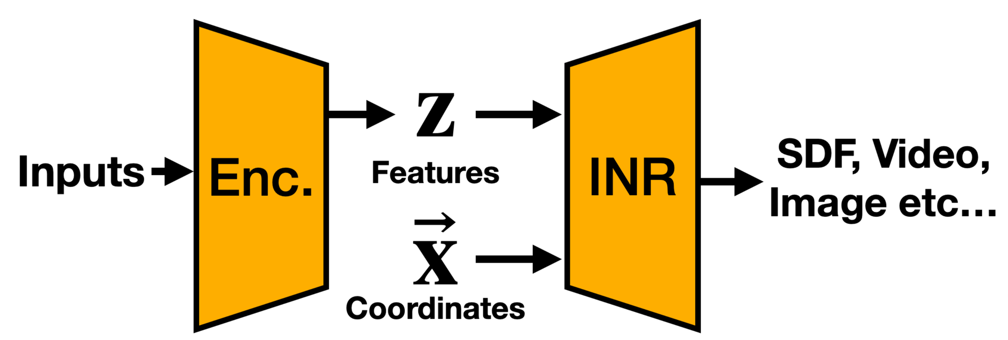


The quantization distorts images with false-contour and blurry artifacts regardless of a bit capability in display devices.

Arbitrary Bitwise Dequantization

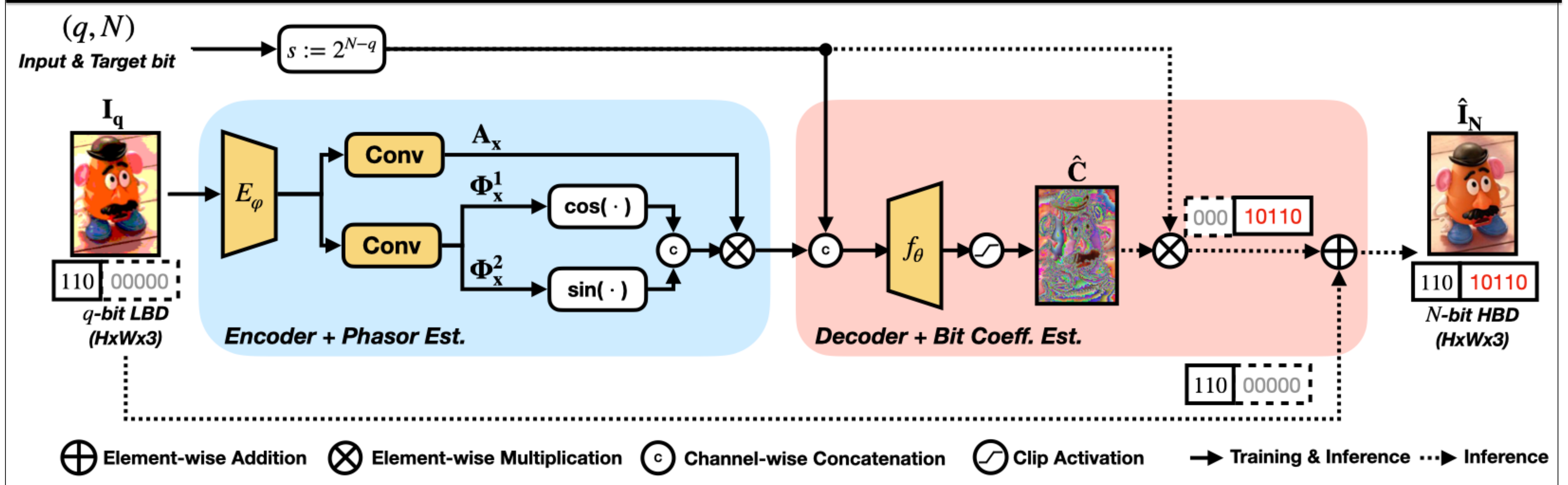
Method	BitNet (18')	BE-CALF (19')	D4/D16 (21')	ABCD (Ours)
False-contour removal	○	△	△	○
High-frequency detail	✕	△	○	○
Unseen inference	✕	✕	✕	○

Local Implicit Neural Representation



- Forward coordinates with latent features
- Locally represent signals with encoded features
- How can we design amplitude-wise INR?

Method



Amplitude Basis & Coefficient

$$\mathbf{I}_N = \sum_{i=N-q}^{N-1} 2^i \cdot \mathbf{B}_i + \sum_{j=0}^{N-q-1} 2^j \cdot \mathbf{B}_j \quad (\text{where } \mathbf{B}_i \in \{0,1\}^{H\times W\times 3})$$

N bits Image q bits LBD ($\triangleq \mathbf{I}_q$) $N-q$ bits Residual

$$= \sum_{i=N-q}^{N-1} 2^i \cdot \mathbf{B}_i + 2^{N-q} \cdot \mathbf{C} \quad (\text{where } \mathbf{C} \in [0,1)^{H\times W\times 3})$$

Basis ($\triangleq s$) of $(\mathbb{F}_2^N, \oplus, \cdot)$ Coefficient of s

INR with Phasor Estimator

$$\mathbf{C}(\mathbf{x}, s) \simeq f_\theta(\mathbf{I}_q[\mathcal{N}(\mathbf{x})], s)$$

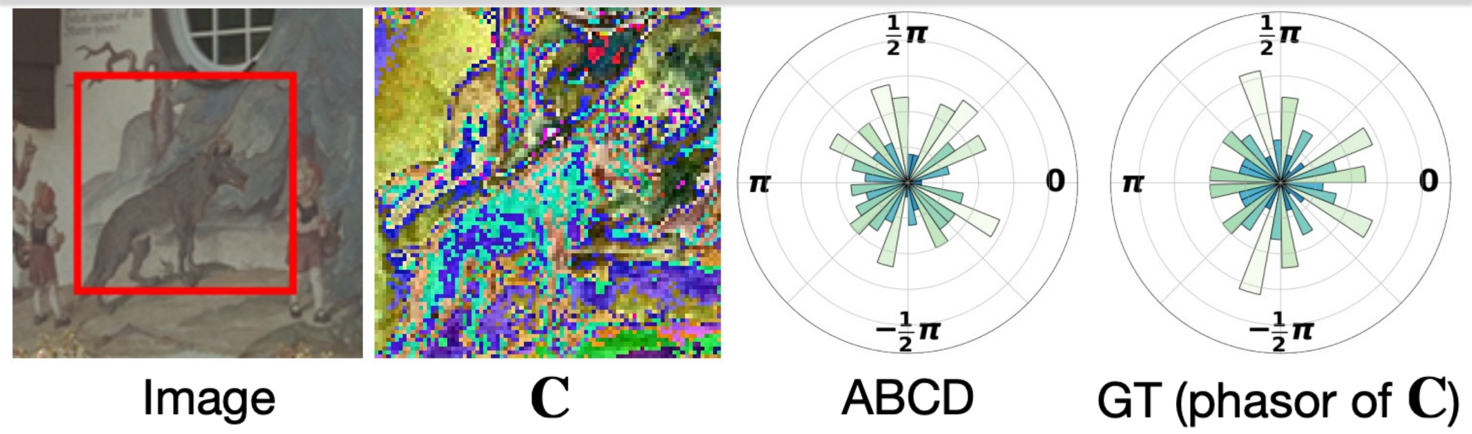
$$\hat{\mathbf{C}}(\mathbf{x}, \mathbf{I}_q, s; \Theta) = f_\theta(h_\psi(\mathbf{z}_\mathbf{x}), s)$$

$$h_\psi(\mathbf{z}_\mathbf{x}) = \begin{bmatrix} \mathbf{A}_\mathbf{x}^1 \\ \mathbf{A}_\mathbf{x}^2 \end{bmatrix} \odot \begin{bmatrix} \cos(\pi \mathbf{\Phi}_\mathbf{x}^1) \\ \sin(\pi \mathbf{\Phi}_\mathbf{x}^2) \end{bmatrix}$$

Phasor Amplitude Phase

Discussion

Learning Dominant Phasor Distribution

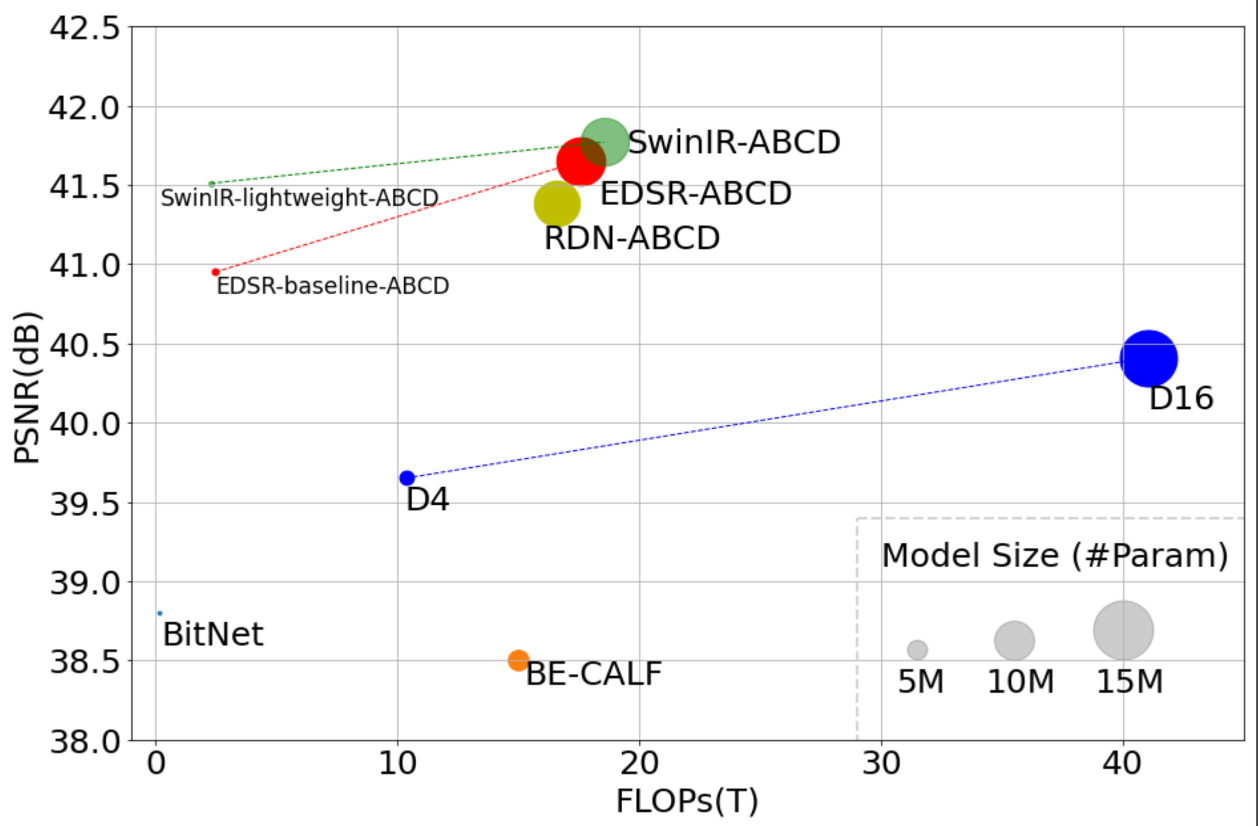


Phasor estimator reformulated from the local texture estimator

$$\mathbf{A}_j \odot \begin{bmatrix} \cos(\pi(\mathbf{F}_j - \delta + h_p(\hat{\mathbf{c}}))) \\ \sin(\pi(\mathbf{F}_j - \delta + h_p(\hat{\mathbf{c}}))) \end{bmatrix}_{\delta=0} \rightarrow \begin{bmatrix} \mathbf{A}_\mathbf{x}^1 \\ \mathbf{A}_\mathbf{x}^2 \end{bmatrix} \odot \begin{bmatrix} \cos(\pi \mathbf{\Phi}_\mathbf{x}^1) \\ \sin(\pi \mathbf{\Phi}_\mathbf{x}^2) \end{bmatrix}$$

Local Texture Estimator ABCD

Model Complexity



Results

Qualitative Comparison

Out-of-Distribution : **2bit →8bit**

Quantitative Comparison

Benchmark	TESTIMAGES 1200						KODAK		ESPL v2	
Method	4 → 8	4 → 12	4 → 16	6 → 12	6 → 16	8 → 16	3 → 8	4 → 8	3 → 8	4 → 8
Input (bit zero-padding)	29.21 0.8764	28.85 0.8741	28.83 0.8739	40.95 0.9856	40.86 0.9855	52.92 0.9990	22.77 0.7671	29.06 0.8998	23.20 0.6616	29.28 0.8261
IPAD	36.29 0.9450	36.20 0.9444	36.18 0.9443	47.20 0.9901	47.15 0.9899	57.84 0.9988	29.20 0.8515	34.90 0.9345	29.86 0.8379	35.75 0.9207
BitNet (0.94M)	38.75 0.9571	38.81 0.9589	38.80 0.9589	49.52 0.9944	49.48 0.9944	53.60 0.9970	32.68 0.9172	38.48 0.9659	32.58 0.9001	38.23 0.9479
BE-CALF (5.18M)	38.45 0.9725	38.50 0.9648	38.50 0.9649	49.85 0.9945	49.84 0.9945	58.11 0.9992	- -	38.92 0.9681	- -	38.43 0.9479
D16 (<15.46M)	40.39 0.9725	40.42 0.9735	40.41 0.9735	52.12 0.9967	52.12 0.9967	61.68 0.9996	33.67 0.9337	39.52 0.9723	33.47 0.9001	39.53 0.9528
EDSR-ABCD (Ours) (12.22M)	41.12 0.9755	41.65 0.9770	41.65 0.9771	52.76 0.9972	52.78 0.9972	61.78 0.9996	34.50 0.9426	40.23 0.9753	34.36 0.9106	40.24 0.9580
SwinIR-ABCD (Ours) (12.10M)	41.29 0.9769	41.76 0.9779	41.77 0.9779	52.82 0.9974	52.83 0.9974	61.78 0.9997	34.62 0.9443	40.31 0.9762	34.55 0.9125	40.35 0.9584

Conclusion

Bitwise coefficient through implicit neural network + Phasor estimator

→ ***Arbitrary bit depth expansion with high-frequency details***