Learned Image Compression with Hierarchical Progressive Context Modeling

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I. Motivation

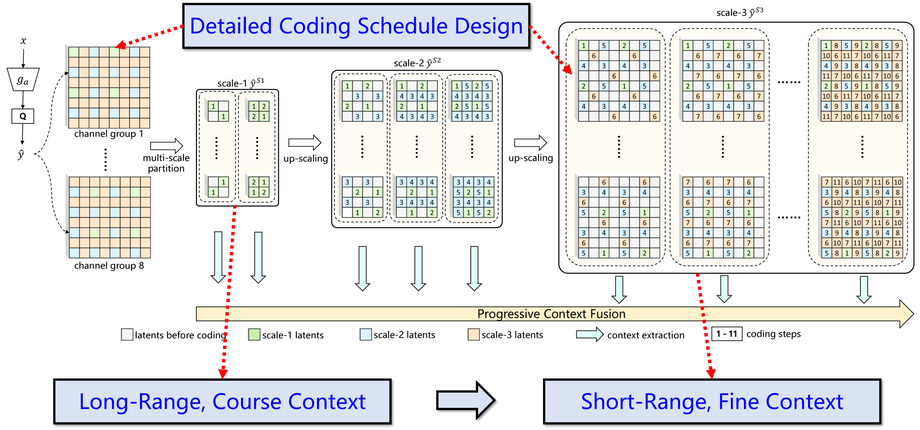
Limitations of existing Learned Image Compression (LIC) methods:

❌Existing methods rely on global attention or dense autoregression to capture long-range dependencies, leading to *inefficient and high-complexity* context modeling.

❌Their ability to *comprehensively exploit diverse contextual information* across coding steps remains limited.

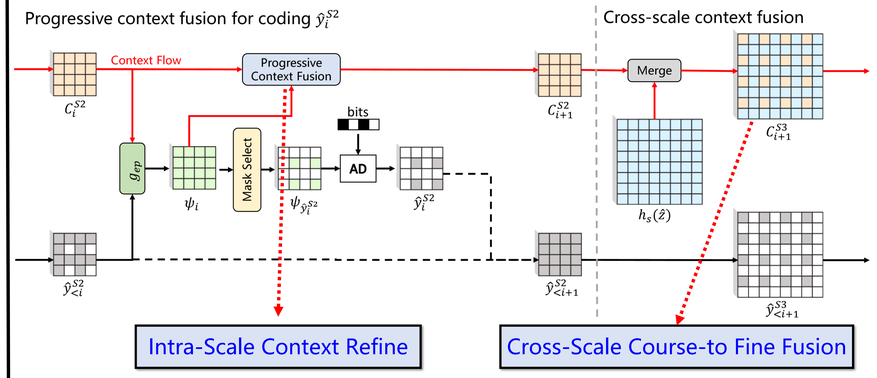
➡️We address these challenges by introducing **Hierarchical Progressive Context Model (HPCM)** that efficiently captures long-range dependencies and progressively fuses multi-scale contextual information.

II. Hierarchical Coding Schedule



Our Hierarchical Coding Schedule divides latent representations into *multiple scales*, sequentially encoding **long-range to short-range dependencies**. This approach efficiently models both global and local contexts, balancing performance and complexity.

III. Progressive Context Fusion



Progressive Context Fusion **progressively integrates context from previous coding steps into the current step** using a cross-attention mechanism. This enables the accumulation of diverse contextual information, enhancing entropy modeling accuracy while maintaining efficiency across multiple scales.

IV. Experiments

Rate-Distortion and Coding Complexity Results

Model	Enc. Time† (ms)	Dec. Time† (ms)	kMACs /pixel	Params (M)	PSNR BD-Rate Kodak	CLIC Pro Valid	Tecnick
ELIC (CVPR'22) [15]	126.5	111.4	573.88	36.93	-3.22%	-3.89%	-4.57%
STF (CVPR'22) [51]	142.5	156.8	511.17	99.86	-2.06%	1.12%	-2.17%
TCM (CVPR'23) [34]	200.2	201.8	1823.58	76.57	-10.70%	-8.32%	-11.84%
MLIC++ (NCW ICML'23) [18]	193.4	226.4	1282.81	116.72	-15.15%	-14.05%	-17.90%
FLIC (ICLR'24) [23]	>1000	>1000	1096.04	70.96	-13.20%	-9.88%	-15.27%
MambaVC (Arxiv'24) [41]	235.6	246.2	813.80	47.88	-8.72%	-	-
WeConvene (ECCV'24) [12]	343.6	256.5	2343.13	107.15	-6.98%	-5.66%	-8.63%
CHARM*	57.5	70.6	495.75	58.53	0.86%	1.55%	-1.32%
DCVC-DC intra*	57.8	58.2	542.14	45.51	-9.18%	-8.54%	-10.18%
HPCM-Base (ours)	81.8	81.3	918.57	68.50	-15.31%	-14.23%	-18.16%
HPCM-Large (ours)	91.2	90.2	1261.29	89.71	**-19.19%**	**-18.37%**	**-22.20%**

*The transforms are the same as our HPCM-Base model, and the entropy models are different.
† Coding time includes network inference time and arithmetic coding time. Details are presented in Sec. F of the supplementary material.

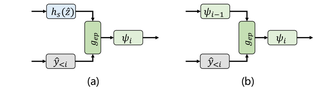
Visual Comparison of Samples from Kodak

Ablation Study

Table 2. Abaltion studies on hierarchical coding schedule.

Model settings	kMACs/pixel	BD-Rate
HPCM-Base*	918.57	0.00%
w/o hierarchical extraction	1107.48	1.07%
coding step (2, 3, 3)	663.90	2.39%
coding step (2, 3, 12)	1427.91	-2.55%
coding step (4, 3, 6)	925.59	0.35%

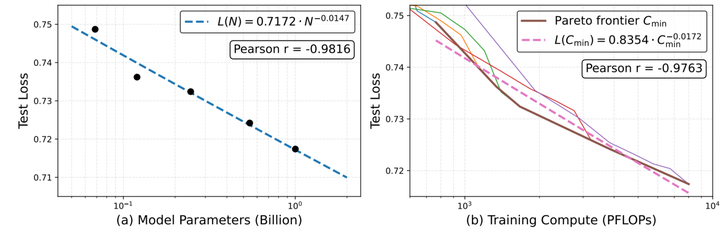
* Our default setting is coding step (2, 3, 6).



Model settings	kMACs/pixel	BD-Rate
HPCM-Base	918.57	0.00%
w/o progressive fusion	872.80	4.71%
use ψ_i as progressive context	872.80	1.17%

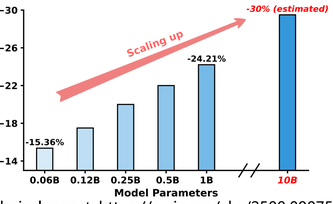
V. Large-Scale Extension of HPCM

Scaling Laws of Large LIC Models



Rate-Distortion and Coding Complexity Results

LALIC (CVPR'25) [16]	189.0	95.4	667.26	66.13	-14.09%	-14.22%	-18.31%
DCAE (CVPR'25) [47]	134.6	132.4	940.40	119.4	-15.36%	-15.40%	-20.35%
HPCM-Base (ICCV'25) [37]	81.8	81.3	918.57	68.5	-15.31%	-14.23%	-18.16%
HPCM-Large (ICCV'25) [37]	91.2	90.2	1261.29	89.71	-19.19%	-18.37%	-22.20%
HPCM-1B	350.9	342.5	9625.24	1002.00	**-24.21%**	**-23.41%**	**-25.68%**



Technical report: https://arxiv.org/abs/2508.09075

Our Code: https://github.com/lyq133/LIC-HPCM

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