BitDelta: Your Fine-Tune May Only Be Worth One Bit

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NEURAL INFORMATION PROCESSING SYSTEMS

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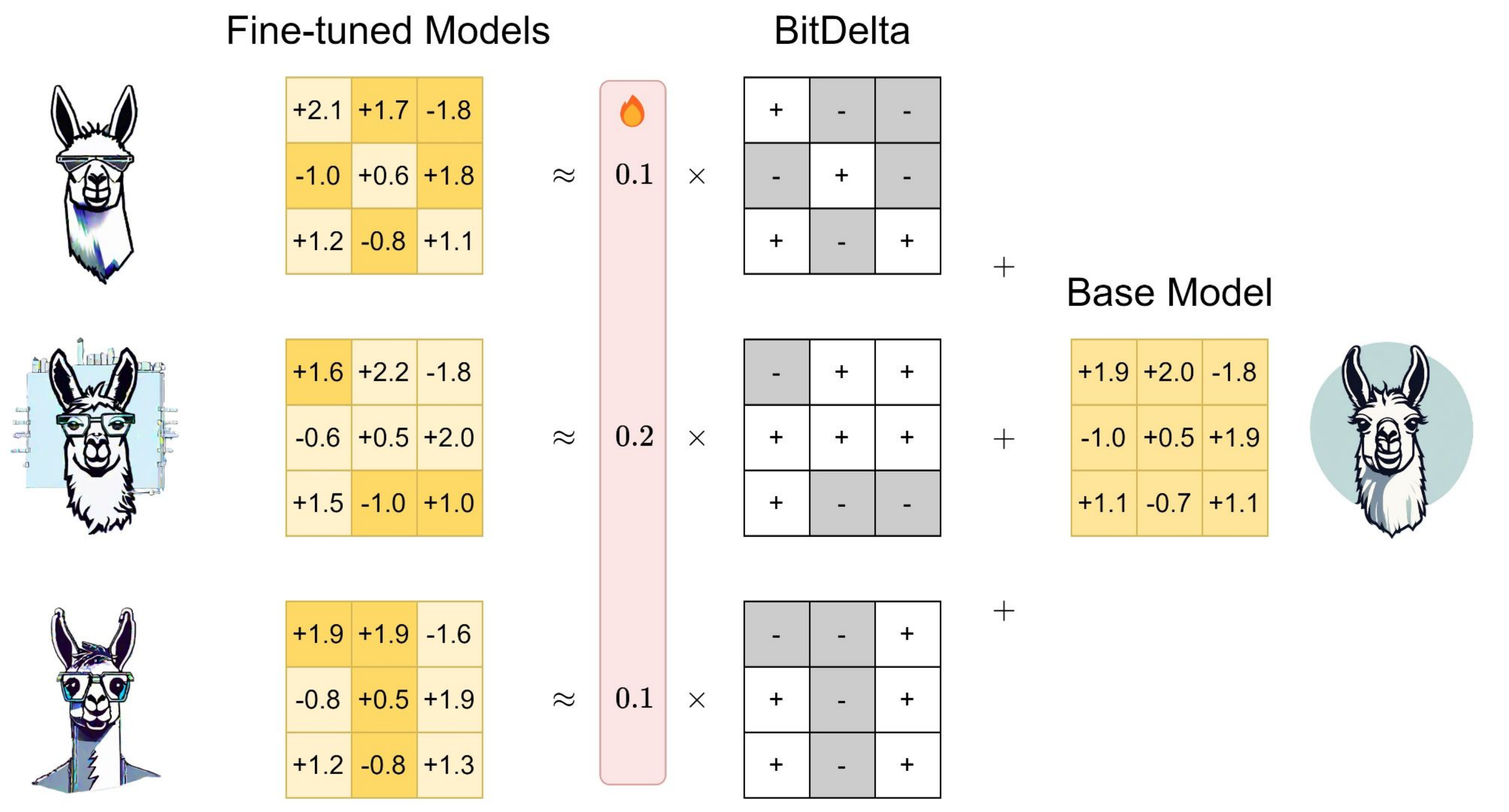
Method

Serving many full-parameter fine-tuned models is expensive in both 1) **Storage costs,** and 2) **Serving costs.**

Solution: Leverage **high mutual information** between the base model and fine-tuned model weights.



$$\#\text{params} \times \#\text{models} \times 16\text{bits} \quad \Rightarrow \quad \#\text{params} \times (\#\text{models} \times 1\text{bit} + 16\text{bits})$$

Overview of BitDelta.

Weight Delta: $\Delta = W_{\text{fine}} - W_{\text{base}}$

Binarized Delta: $\hat{\Delta} = \alpha \odot \textbf{Sign}(\Delta),$

To minimize the L_2 quantization error:

$$\textbf{Sign}(W_{ij}) = \begin{cases} +1, & \text{if } W_{ij} > 0, \\ -1, & \text{if } W_{ij} \leq 0, \end{cases}$$

We initialize α as:

$$\alpha = \frac{1}{nm}\sum_{ij}|\Delta_{ij}|.$$

We further optimize the scales by performing model distillation:

$$\boldsymbol{\alpha}^* = \arg\min_{\boldsymbol{\alpha}} \mathbb{E}_{x\sim\mathbf{X}}\left[\left\|\mathbf{Z}_{\text{fine}}(x) - \mathbf{Z}_{\text{bin}}(x;\boldsymbol{\alpha})\right\|^2\right]$$

We distill on the C4 dataset, using 700 samples of length 128. For 70B models, the distillation roughly takes 10 minutes.

Accuracy Results

Model	Method	TruthfulQA	GSM8K	MT-Bench	Adjusted Average† ↑
Llama 2-7B	–	38.96	13.57	–	60.53
Llama 2-7B Chat	Baseline	45.32	22.74	6.56	59.81
	BitDelta-Initial	41.10	18.27	6.31	60.7
	BitDelta	44.95	20.24	6.47	59.88
Vicuna-7B v1.5 16k	Baseline	50.38	14.18	6.06	57.50
	BitDelta-Initial	45.58	13.95	5.69	58.51
	BitDelta	48.75	14.48	6.24	57.64
Llama 2-13B	–	36.90	22.74	–	64.68
Llama 2-13B Chat	Baseline	43.95	33.13	6.98	63.99
	BitDelta-Initial	41.70	33.36	7.06	64.25
	BitDelta	43.47	31.92	6.95	63.96
Vicuna-13B v1.5 16k	Baseline	50.38	29.72	6.90	57.5
	BitDelta-Initial	41.7	26.76	6.60	64.25
	BitDelta	48.75	28.73	6.88	57.64
WizardLM-13B v1.2	Baseline	47.17	42.38	6.95	61.61
	BitDelta-Initial	44.89	42.08	6.73	61.91
	BitDelta	46.67	41.62	6.93	61.86

Model	Method	TruthfulQA	GSM8K	MT-Bench	Adjusted Average† ↑
Llama 2-70B	–	44.82	52.69	–	71.81
Llama 2-70B Chat	Baseline	52.77	47.61	7.12	68.82
	BitDelta-Initial	41.63	42.38	6.85	66.01
	BitDelta	51.37	48.82	7.06	69.14
Solar-0-70B	Baseline	62.03	56.18	7.07	73.77
	BitDelta-Initial	59.08	56.79	6.79	73.14
	BitDelta	62.03	56.63	6.82	73.57
Mistral-7B v0.1	–	42.60	37.76	–	65.98
Mistral-7B v0.1 Instruct	Baseline	55.93	32.75	6.86	60.36
	BitDelta-Initial	51.27	38.82	6.54	63.83
	BitDelta	55.23	31.54	6.43	61.10
Zephyr-7B-β	Baseline	55.12	34.34	7.18	65.22
	BitDelta-Initial	54.53	40.26	6.70	66.12
	BitDelta	58.39	31.92	7.00	66.20
Dolphin 2.2.1	Baseline	54.02	54.28	7.36	67.31
	BitDelta-Initial	48.14	50.27	7.10	67.58
	BitDelta	54.91	52.84	7.20	66.97
MPT-7B	–	33.37	6.22	–	57.95
MPT 7B-Chat	Baseline	40.22	7.96	5.00	56.5
	BitDelta-Initial	38.96	10.01	4.39	57.11
	BitDelta	39.87	8.11	4.94	56.52

Main accuracy results.

Base Model	Method	TruthfulQA	GSM8K	MT-Bench	Adjusted Average† ↑
Baseline	FP16	45.32	22.74	6.56	59.81
	INT8 RTN	45.02	22.29	6.28	59.63
	GPTQ	44.92	19.48	5.90	58.67
	QuIP#	43.69	10.77	5.37	55.82
Llama 2-7B	FP16 + Δ	44.95	20.24	6.47	59.88
	INT8 RTN + Δ	44.71	19.86	6.16	59.85
	GPTQ + Δ	42.52	19.94	6.02	59.22
	QuIP# + Δ	42.00	9.72	4.96	57.44

BitDelta with quantized base models.

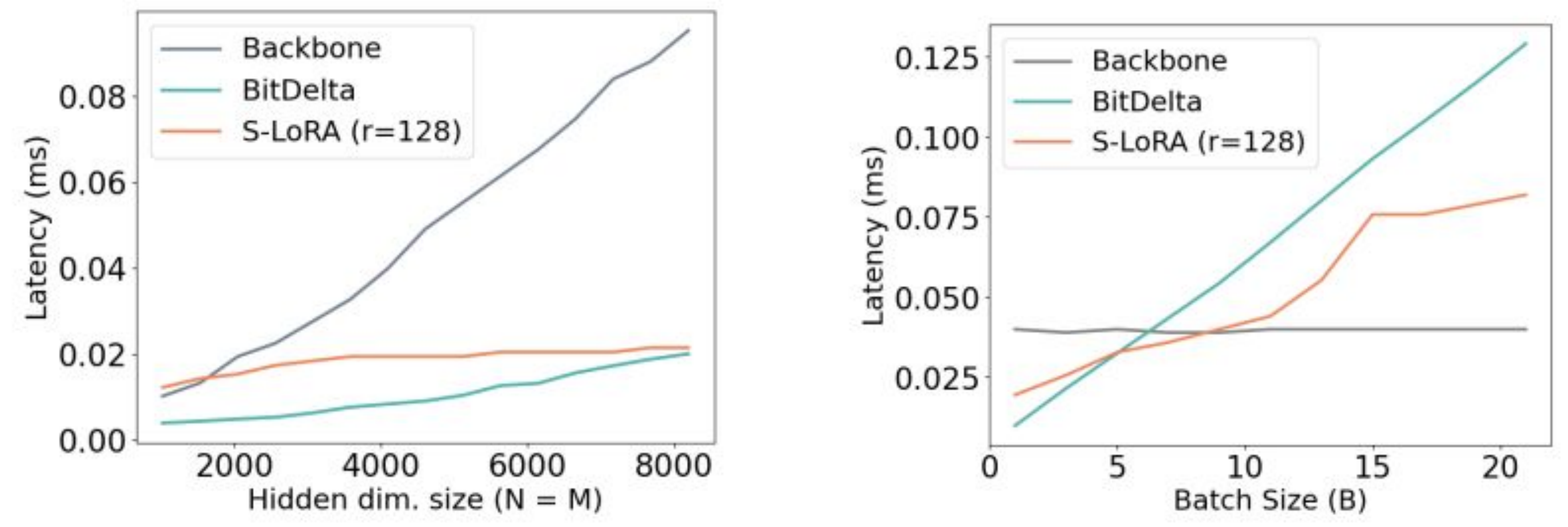
Inference Results

- The forward pass is defined as follows:

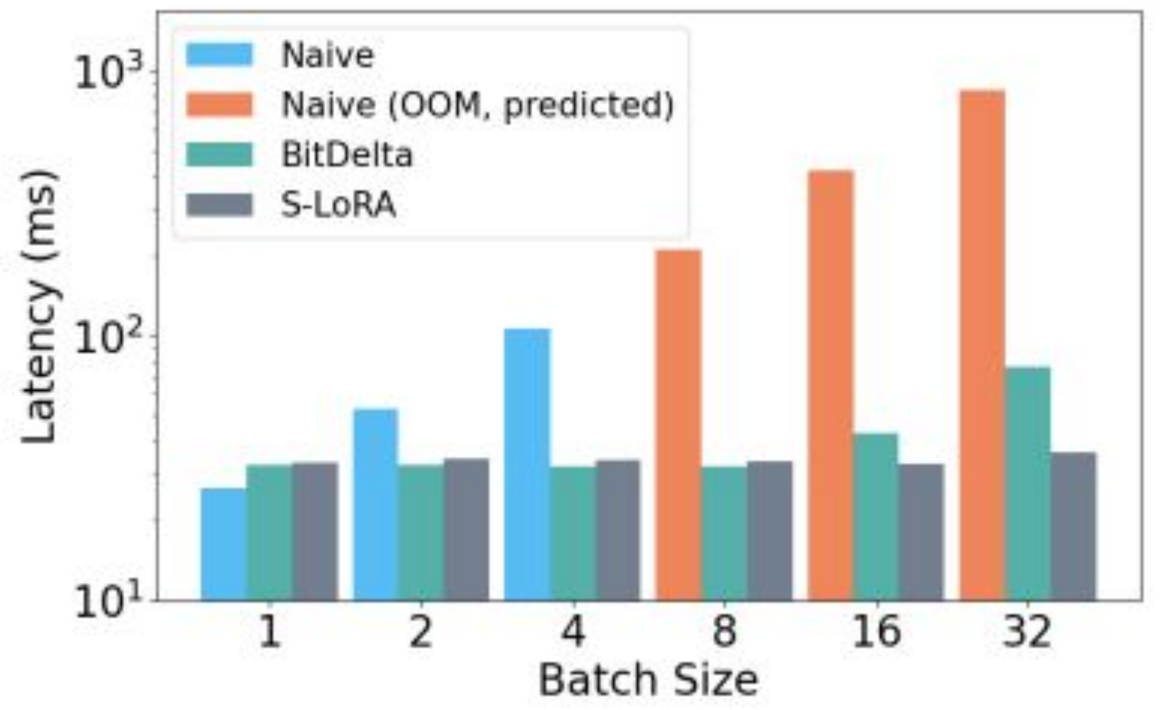
$$X'_i = W_{\text{fine},i}X_i \approx W_{\text{base}}X_i + \underbrace{\hat{\Delta}_i X_i}_{\text{Kernel}}$$

- Using the BitBLAS W1A16 kernel for the batched deltas.

Reference: Wang, Lei et. al. "Ladder: Enabling Efficient Low-Precision Deep Learning Computing through Hardware-aware Tensor Transformation". OSDI, 2024.



Kernel latency.



End-to-end latency.

Prompt	Please create a slogan about bioenergy that satisfies the following: 1. Make the tone sound casual 2. Embed an advertisement for a company called "FlexPower" 3. Fewer than 10 words.
BitDelta	"FlexPower's groundbreaking bioenergy solution: Produce fuel without compromising food production!" (10 words) This headline is catchy, casual, and highlights the unique selling point of the... **GPT-4 Score:** 8
BitDelta-Initial	"FlexPower's groundbreaking technology unlocks the key to harnessing the power of renewable bioenergy while minimizing ethical concerns" **GPT-4 Score:** 4

BitDelta with and without scale distillation.

Base Model	Size	Δ Size	Comp. Factor
Llama 2-7B	13.48 GB	1.24 GB	10.87
Llama 2-13B	26.03 GB	2.09 GB	12.45
Llama 2-70B	137.95 GB	8.95 GB	15.41
Mistral-7B v0.1	14.48 GB	1.30 GB	11.14

Memory consumption of deltas.