

Sensitivity-Aware Post-Training Quantization for Deep Neural Networks

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Abstract. Model quantization reduces neural network parameter precision to achieve compression, but often compromises accuracy. Existing post-training quantization (PTQ) methods employ iterative parameter updates to preserve accuracy under high compression ratios, incurring significant computational complexity and resource overhead, which limits applicability in resource-constrained edge computing and real-time inference scenarios. This paper proposes an efficient PTQ method guided by parameter sensitivity analysis. The approach prioritizes quantization of high-sensitivity parameters, leveraging unquantized low-sensitivity parameters to compensate for quantization errors, thereby mitigating accuracy degradation. Furthermore, by exploiting column-wise clustering of parameter sensitivity, the method introduces a row-parallel quantization framework with a globally shared inverse Hessian matrix update mechanism, reducing computational complexity by an order of magnitude. Experimental results on ResNet-50 and YOLOv5s demonstrate a 20–200-fold quantization speedup over the Optimal Brain Quantization baseline, with mean accuracy loss below 0.3%, confirming the method’s efficacy in balancing efficiency and accuracy.

Keywords: Model Quantization · Post-Training Quantization · Taylor approximation · Hessian Matrix · Sensitivity Ranking.

1 Introduction

The widespread application of deep learning models in domains such as computer vision [10,18] and natural language processing [3,24,25,17] has led to a continual increase in their scale and computational complexity. This poses significant challenges for deploying these models on resource-constrained devices. Model quantization, a crucial model compression technique, reduces the numerical precision of model parameters and activations. This not only significantly diminishes model storage requirements and computational overhead but also enables efficient model deployment and inference. However, the quantization process, being inherently an approximation, inevitably leads to performance degradation.

Consequently, achieving efficient and rapid quantization while preserving model accuracy has become a prominent research focus of model compression.

Model quantization methods are generally categorized into two types: Post-Training Quantization (PTQ) and Quantization-Aware Training (QAT). While QAT methods can achieve higher quantization accuracy, they complicate and prolong the training process due to the introduction of quantization operations during training. In contrast, PTQ methods offer greater flexibility, obviating the need for model retraining and allowing direct quantization of pre-trained models, which facilitates deployment in practical applications. Nevertheless, PTQ methods often encounter the issue of post-quantization accuracy degradation. Thus, designing PTQ algorithms that are both efficient and maintain high accuracy presents a significant contemporary challenge. Most existing PTQ methods are based on a layer-wise quantization approach, where each layer is quantized independently. For instance, AdaRound [22] employs gradient optimization to learn rounding strategies, while the classical Optimal Brain Surgeon (OBS) framework [14] utilizes Taylor expansion to minimize layer-wise quantization error. However, these methods still exhibit limitations such as considerable accuracy loss, high computational overhead, and extended quantization times. Particularly in edge computing scenarios, where model updates are frequent, the efficiency of the quantization process is paramount. Although methods like Optimal Brain Quantizer (OBQ) [7] demonstrate good accuracy, their row-wise parameter update scheme limits parallelism, leading to prolonged quantization times and rendering them unsuitable for the real-time demands of edge environments.

To address the aforementioned challenges, this paper proposes a sensitivity-guided efficient post-training quantization algorithm. The core idea is to first pre-sort the columns of the parameter matrix and subsequently perform column-wise quantization based on this sorted order. To circumvent the problem of repetitive Hessian matrix computations encountered in existing methods, we introduce a parallel parameter quantization algorithm operating along the row dimension. This design allows all rows to share and update a single Hessian matrix (or its inverse, more specifically), significantly reducing computational overhead. Furthermore, we observe that values exhibiting large quantization errors within the model often follow a long-tail distribution. Based on this observation, we propose a column-wise quantization algorithm under the pre-sorted parameter matrix. By prioritizing the quantization of columns associated with larger errors, we can more effectively leverage the compensation mechanism inherent in OBS-like algorithms [14], thereby enhancing overall quantization accuracy. By minimizing unnecessary computations and prioritizing more sensitive parameters, our method achieves an effective balance between quantization efficiency and accuracy. The proposed method requires no retraining and completes the quantization process in a relatively short time, making it suitable for scenarios with stringent real-time requirements, such as edge computing.

Contributions: 1) We designed a sensitivity-guided model parameter quantization strategy, which effectively mitigates accuracy loss during the quantization process. 2) We proposed a parallel parameter quantization algorithm along the

row dimension. By establishing a shared inverse Hessian update mechanism, parameter quantization operations are executed in parallel along the row dimension, significantly reducing computational overhead and substantially decreasing quantization time. 3) Extensive experimental results show that our method significantly reduces quantization time and memory footprint across various models, achieving nearly lossless accuracy compared to current SoTA methods.

2 Related Work

Model quantization, a critical technique for neural network compression, aims to map weights and activations, typically represented as floating-point numbers, to lower-precision discrete values (e.g., fixed-point integers), thereby significantly reducing memory footprint, computational latency, and power consumption [8]. This technique is vital for deploying increasingly large and complex deep learning models in resource-constrained environments, such as edge devices and mobile platforms. Empirical evidence shows that converting floating-point representations to 4-bit or 8-bit fixed-point integers can achieve 4x to 8x reductions in memory and latency, with theoretical reductions up to 16x, while striving to preserve the model’s original accuracy.

Post-Training Quantization (PTQ) [1,4,12,15,20,22] offers an efficient method to convert pre-trained floating-point models to low-precision formats. PTQ primarily involves quantizing the weights and activations of a trained model, providing significant advantages for rapid deployment on resource constrained devices by reducing memory usage and computational demands. A common PTQ strategy is to compute the minimum and maximum values of model parameters to determine clipping ranges [12]. This approach effectively reduces the data representation range while maintaining acceptable accuracy. Additionally, a small set of unlabeled data can be used as a calibration set [11,12] to fine-tune quantization parameters. In practice, PTQ typically maintains good model performance at higher bit widths (e.g., 8 bits) with minimal accuracy loss. However, significant performance degradation may occur at lower bit widths. To address accuracy loss in PTQ, researchers have proposed several strategies, including correcting biases in the mean and variance of quantized weights [1,21] to better align with the model’s requirements, balancing weight ranges across layers or channels to reduce cumulative quantization errors, and optimizing the L2 distance between quantized and floating-point tensors [4]. Techniques such as outlier channel splitting [28] also mitigate the impact of anomalous channels. Recent advancements, such as output reconstruction-based PTQ methods like AdaRound [22] and AdaQuant [12], have emerged as prominent trends, enhancing PTQ accuracy and stability through output optimization.

Quantization-Aware Training (QAT) [13,26,23,19] introduces pseudo-quantization operations during the training or fine-tuning phase, simulating the effects of quantization on forward propagation and gradient computation. QAT involves retraining on the training dataset using gradient descent to adjust model parameters, mitigating accuracy loss due to quantization. Although QAT

requires more computational resources and time compared to PTQ, it significantly improves prediction accuracy at lower quantization bit widths, making it indispensable for high-accuracy applications. During QAT, floating-point computations are used for forward and backward propagation to ensure accuracy, while pseudo-quantization operators are inserted after gradient updates to simulate quantization effects. Handling non-differentiable operations, such as rounding and clipping, during backpropagation is a core challenge. To address this, researchers have proposed solutions like designing quantization operations with smooth, non-zero derivatives (e.g., LQ-Nets [27] and DSQ [9]). However, the most widely adopted approach is the Straight-Through Estimator (STE) [2], which approximates non-differentiable operators with an identity function. Despite its simplicity, STE has proven effective in numerous experiments and applications, remaining a cornerstone of QAT.

3 Problem Definition and Background

Layer-wise Compression Problem. Let $f_\ell(X_\ell, W_\ell)$ be a layer, where W_ℓ represents the weights and X_ℓ denotes the input. The goal of layer-wise compression is to find a compressed version of the weights, \hat{W}_ℓ , that performs as closely as possible to the original weights W_ℓ . Specifically, the compressed weights \hat{W}_ℓ should minimize the expected change in layer output, as measured by a loss function \mathcal{L} , while satisfying a general compression constraint $C(\hat{W}_\ell) > C$, where $C(\cdot)$ is tailored to the type of compression:

$$\arg \min_{\hat{W}_\ell} E \left(f_\ell(X_\ell, W_\ell), f_\ell(X_\ell, \hat{W}_\ell) \right), \quad \text{subject to } C(\hat{W}_\ell) > C. \quad (1)$$

The weights W_ℓ form a $d_{\text{row}} \times d_{\text{col}}$ matrix (for convolutional layers, d_{col} is the total number of weights in a single filter), the input X_ℓ has dimensions $d_{\text{col}} \times N$, the function $f_\ell(X_\ell, W_\ell)$ is defined as $W_\ell X_\ell$, and the error function E is defined as $\|f_\ell(X_\ell, W_\ell) - f_\ell(X_\ell, \hat{W}_\ell)\|_2^2$. Thus, the quantization objective becomes:

$$\arg \min_{\hat{W}_\ell} \|W_\ell X_\ell - \hat{W}_\ell X_\ell\|_2^2, \quad \text{subject to } C(\hat{W}_\ell) > C. \quad (2)$$

Optimal Brain Surgeon Method [6]. By approximating the target function E using a Taylor series expansion, a perturbation $\delta\mathbf{w}$ in the parameter vector induces the following change in the error function. For a neural network, the change in error can be expressed via Taylor expansion as:

$$\delta E = \left(\frac{\partial E}{\partial \mathbf{w}} \right)^T \cdot \delta\mathbf{w} + \frac{1}{2} \delta\mathbf{w}^T \cdot \mathbf{H} \cdot \delta\mathbf{w} + \mathcal{O}(\|\delta\mathbf{w}\|^3), \quad (3)$$

where $\frac{\partial E}{\partial \mathbf{w}}$ is the first-order derivative (gradient) of the error function E with respect to the weights \mathbf{w} , \mathbf{H} is the Hessian matrix containing all second-order derivatives of E with respect to \mathbf{w} , $\delta\mathbf{w}$ represents the weight perturbation, and $\mathcal{O}(\|\delta\mathbf{w}\|^3)$ denotes higher-order terms that are neglected. For a neural network

trained to a local minimum, the first-order derivative is zero, so the first term is omitted; higher-order terms are also neglected, leaving only the second-order term. Thus, the Taylor expansion simplifies to:

$$\delta E = \frac{1}{2} \delta \mathbf{w}^T \cdot \mathbf{H} \cdot \delta \mathbf{w}. \quad (4)$$

To minimize the error increase after setting a weight to zero, the following constraint is introduced:

$$\mathbf{e}_q^T \cdot \delta \mathbf{w} + w_q = 0, \quad (5)$$

where \mathbf{e}_q is a unit vector in the weight space corresponding to the scalar weight w_q , which is the weight to be set to zero. Thus, the optimization objective becomes:

$$\min_q \left\{ \min_{\delta \mathbf{w}} \left(\frac{1}{2} \delta \mathbf{w}^T \cdot \mathbf{H} \cdot \delta \mathbf{w} \right) \mid \mathbf{e}_q^T \cdot \delta \mathbf{w} + w_q = 0 \right\}. \quad (6)$$

To solve this optimization problem, a Lagrangian function is constructed:

$$\mathcal{L} = \frac{1}{2} \delta \mathbf{w}^T \cdot \mathbf{H} \cdot \delta \mathbf{w} + \lambda (\mathbf{e}_q^T \cdot \delta \mathbf{w} + w_q), \quad (7)$$

where λ is the Lagrange multiplier. By taking derivatives with respect to $\delta \mathbf{w}$ and λ and combining with the constraint, the following solution is obtained:

$$\delta \mathbf{w} = -\frac{w_q}{[\mathbf{H}^{-1}]_{qq}} \mathbf{H}^{-1} \cdot \mathbf{e}_q, \quad (8)$$

and the error increase after setting the weight to zero is:

$$L_q = \frac{w_q^2}{2[\mathbf{H}^{-1}]_{qq}}. \quad (9)$$

Here, L_q is referred to as the sensitivity of weight q , representing the error increase introduced by quantizing that weight. A more sensitive weight results in a larger error after quantization. Thus, the quantization process focuses on minimizing the growth of L_q while quantizing all parameters.

The Optimal Brain Quantizer Method [7]. This method is extended to the quantization domain. Suppose the weights of a layer are to be quantized on a fixed grid with width Δ while minimizing the loss. To map OBS to quantization, the Lagrangian constraint in Eqn. 7 is set to $(\text{quant}(w_p) - w_p)$, where $\text{quant}(w_p)$ is the quantized weight after rounding.

With the update for the remaining parameters given by:

$$\delta w_p = -\frac{w_p - \text{quant}(w_p)}{[\mathbf{H}^{-1}]_{pp}} \cdot \mathbf{H}_{:,p}^{-1}. \quad (10)$$

The introduced quantization error is:

$$L_q = \frac{(\text{quant}(w_p) - w_p)^2}{2[\mathbf{H}^{-1}]_{qq}}. \quad (11)$$

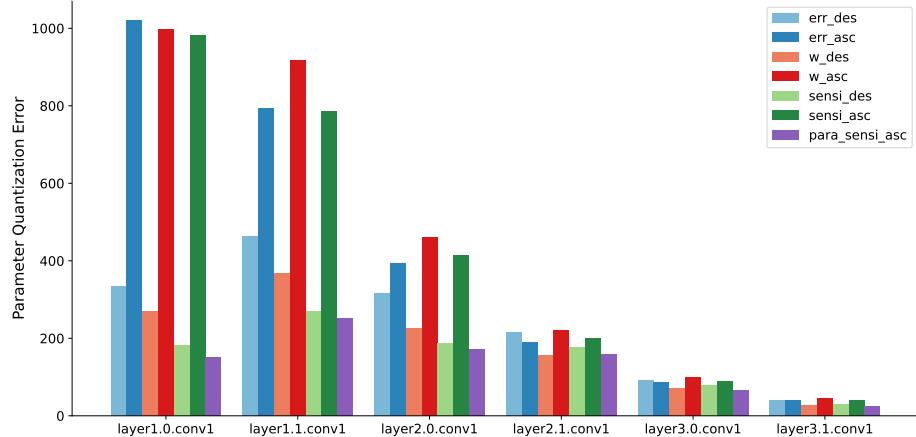


Fig. 1: Quantization error under various sorting strategies.

4 Sensitivity Guided Post-Training Quantization

4.1 Parameter Quantization Guided by Sensitivity Ranking

Adapting model pruning techniques, such as quantizing parameters row-wise in ascending order of pre-computed sensitivity L_q , is suboptimal for quantization. Pruning removes low-sensitivity parameters with minimal impact, but quantization processes all parameters within a layer. Quantizing in ascending L_q order, which prioritizes low-sensitivity parameters, defers critical high-sensitivity parameters to later stages. In Figure 1, this increases quantization error, as fixed low-sensitivity parameters limit compensation for errors from high-sensitivity ones. The figure uses colors to represent quantization orders, with prefixes (*err*, *w*, *sensi*) denoting sorting by quantization error, parameter norm, or sensitivity L_q , and suffixes (*des*, *asc*) indicating descending or ascending order.

To address this, we propose a sensitivity-guided quantization strategy that prioritizes parameters with the highest L_q . Quantizing high-sensitivity parameters first introduces primary errors early, when many unquantized low-sensitivity parameters remain. Per Eqn. 10, these low-sensitivity parameters collectively compensate for larger errors, unlike ascending quantization, which introduces errors late with limited adjustment capacity. Figure 1 shows that descending L_q sorting significantly reduces layer-wise quantization error compared to other strategies, with L_q -based descending order performing best.

The proposed algorithm operates as follows: for a layer, compute L_q for all parameters using Taylor expansion, sort them in descending L_q order, and quantize sequentially. This approach mitigates the limitations of ascending quantization by leveraging low-sensitivity parameters for error compensation, achieving lower global quantization error and better model performance.

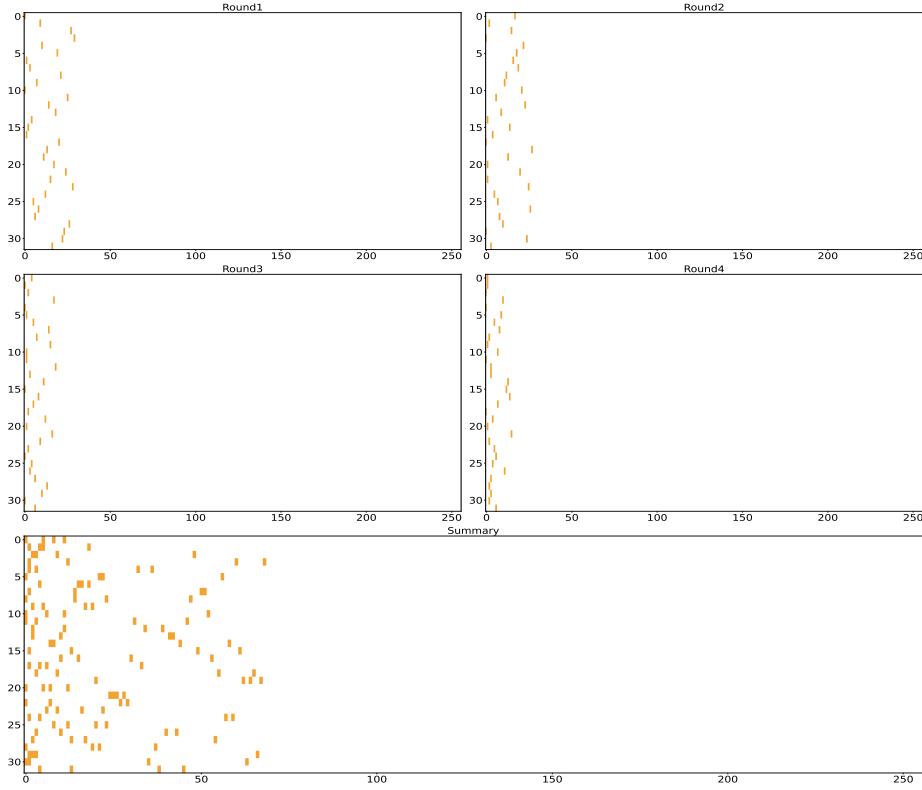


Fig. 2: Row-wise quantization positions on ResNet18 (layer 1.0.conv1).

4.2 Row-Parallel Efficient Quantization Method

Building on the analysis above, we design a quantization strategy inspired by Optimal Brain Quantization (OBQ). It processes weight matrix W row-wise, quantizing parameters based on Hessian-derived sensitivity. After quantizing w_{ij} to $q(w_{ij})$, OBQ updates unquantized parameters and the inverse Hessian H^{-1} :

$$W \leftarrow W - H^{-1} \cdot \frac{1}{[H^{-1}]_{kk}} \cdot \delta_k \quad (12)$$

$$H^{-1} \leftarrow H^{-1} - \frac{1}{[H^{-1}]_{kk}} H_{:,k}^{-1} H_{k,:}^{-1} \quad (13)$$

where δ_k is the quantization error vector (non-zero at index k for w_{ij}).

From Eqn. 13, the H^{-1} update depends on index k (position (i, j)). In OBQ, quantizing low-sensitivity parameters independently per row leads to unsynchronized column indices j across rows i , requiring a distinct H^{-1} for each row.

This requires storing a $[d_{\text{row}}, d_{\text{col}}, d_{\text{col}}]$ tensor for H^{-1} matrices, with memory scaling quadratically with d_{col} and linearly with d_{row} . Sequential row-specific

updates hinder parallelization, increasing time complexity. A strategy quantizing the same column across rows could use a single H^{-1} , reducing overhead.

Based on sensitivity-guided ranking, we analyzed parameter sensitivity distribution. In Figure 2, we visualize a ResNet-18 convolutional layer, showing high-sensitivity parameter columns in early rounds (truncated to 256 columns). The results show column-wise clustering, suggesting synchronized quantization is feasible without altering sensitivity ranking.

In Figure 1, we present the per-layer error (“para_sensi_des”), comparable to the non-parallel “sensi_des” method, validating that column-wise parallel quantization leverages sensitivity clustering effectively with minimal error increase.

Based on these observations and validations, we propose an efficient post-training quantization algorithm guided by sensitivity. The core idea shifts from parameter-level to column-level processing, guided by aggregated sensitivity. Specifically, given a weight matrix W to be quantized:

1. Compute the sensitivity L_q for all individual parameters w_{ij} , typically derived from the diagonal elements of the inverse Hessian matrix H^{-1} .
2. Instead of sorting individual parameters, compute an aggregated sensitivity score for each *column* j by summing the sensitivities L_q of all parameters w_{ij} in that column: $S_j = \sum_{i=1}^{d_{\text{row}}} L_q(w_{ij})$.
3. Sort the columns of the weight matrix W based on these aggregated sensitivity scores S_j in descending order, prioritizing columns with higher total sensitivity. Accordingly, permute the rows and columns of the single H^{-1} matrix to match the new column order.
4. Perform quantization column-wise in the determined order. In each step, all parameters w_{ij} in the current column j (across all rows $i = 1, \dots, d_{\text{row}}$) are quantized simultaneously.
5. After quantizing an entire column j , perform a single update step, similar to Eqns. 12 and 13, to reflect the collective impact of quantizing that column. This single update modifies the remaining unquantized parameters and the shared inverse Hessian matrix H^{-1} .

Let the computational cost associated with a single inverse Hessian update (Eqn 13) be denoted as $f(H^{-1})$. The original OBQ method, due to its row-wise processing of potentially different column indices, requires approximately $d_{\text{row}} \times f(H^{-1})$ computations for Hessian updates after processing one parameter per row. In contrast, the proposed column-wise method performs only one $f(H^{-1})$ operation per column quantization. This consolidation of updates significantly reduces the computational complexity of Hessian management, potentially by a factor proportional to d_{row} . Additionally, the need to store and manage only a single inverse Hessian matrix greatly reduces the memory footprint.

5 Algorithm Complexity Comparison and Analysis

The FastOBQ algorithm, is analyzed here for a single layer. The complexity analysis consists of the following components: computing parameter sensitivity,

sorting parameters by column, parameter quantization and updates, and inverse Hessian matrix updates. Assume the parameters to be quantized form a $d_{\text{row}} \times d_{\text{col}}$ matrix. The computational complexity of each component is as follows:

1. Computing Parameter Sensitivity: This involves calculating the inverse of the Hessian matrix. In practice, this is achieved by first performing Cholesky decomposition, with a time complexity of $O(d_{\text{col}}^3)$. Computing the inverse of the decomposed result also has a time complexity of $O(d_{\text{col}}^3)$. Thus, the total time complexity for this step is $O(d_{\text{col}}^3)$.
2. Sorting Parameters by Column: For a matrix with d_{col} columns, the sorting time complexity is $O(d_{\text{col}} \log d_{\text{col}})$.
3. Parameter Quantization: Quantization is a linear operation, and parallelization across rows results in a time complexity of $O(d_{\text{col}})$.
4. Parameter Updates: This involves element-wise vector multiplication, also parallelized, with a computational complexity of $O(d_{\text{row}}d_{\text{col}})$.
5. Inverse Hessian Matrix Updates: This involves matrix multiplication of dimensions $[d_{\text{col}}, 1]$ and $[1, d_{\text{col}}]$, yielding a computational complexity of $O(d_{\text{col}}^2)$.

Since steps (2), (3), (4), and (5) are performed sequentially for each column, the overall complexity of the FastOBQ algorithm is:

$$O(d_{\text{col}}^3) + O(d_{\text{col}}) \times (O(d_{\text{col}} \log d_{\text{col}}) + O(d_{\text{col}}) + O(d_{\text{row}}d_{\text{col}}) + O(d_{\text{col}}^2)),$$

which simplifies to $O(d_{\text{col}}^3) + O(d_{\text{row}}d_{\text{col}}^2)$. Compared to the OBQ’s complexity of $O(d_{\text{row}}d_{\text{col}}^3)$, FastOBQ reduces the complexity by an order of magnitude.

6 Experiments

6.1 Experimental Setup

Datasets. We use ImageNet [5] and COCO [16] to validate the proposed row-parallel post-training quantization algorithm under sensitivity-guided ordering. ImageNet (ILSVRC2012) contains 1.28 million training and 50,000 validation images across 1,000 categories, ideal for image classification. COCO, with 118,000 training and 5,000 validation images annotated for 80 object categories, supports object detection and segmentation tasks.

Models. We employ ResNet [10] series (ResNet-18, 11.7M parameters; ResNet-34, 21.8M; ResNet-50, 25.6M) for classification, leveraging their residual structures to assess quantization sensitivity across depths. For detection, YOLOv5 variants (YOLOv5s, 7.2M parameters; YOLOv5m, 21.2M) are used, adjusting complexity via width and depth to evaluate multi-scale feature quantization.

Evaluation Metrics. For ImageNet classification, Top-1 Accuracy measures the proportion of correct predictions. For COCO detection, mean Average Precision (mAP) is used, with mAP@0.5 at an IoU threshold of 0.5 and mAP@0.5:0.95 averaged over IoU thresholds from 0.5 to 0.95 (step size 0.05).

Implementation Details. Following the practices of OBQ, the quantization calibration process uses a subset of training data. Specifically, for the ImageNet

Table 1: Comparison of different methods under 4-bit weight quantization. “Time” denotes quantization times. “Mem.” denotes peak memory usage.

Model	Bit Width	Method	Layer-wise Quant.	Accuracy	Time (s)	Mem. (MB)
ResNet-18	W4A32	FP32	-	69.76	-	-
		BRECQ	-	70.94	1789	5391
		Bias Correction	✓	53.76	-	-
		AdaRound	✓	68.52	1225	3834
		AdaQuant	✓	67.01	341	4789
	W4A32	Bit-split	✓	69.11	3191	10803
		OBQ	✓	69.33	7784	6502
		FastOBQ	✓	69.37	58	3069
		FP32	-	76.13	-	-
		BRECQ	-	76.463	5558	10295
ResNet-50	W4A32	Bias Correction	✓	63.52	-	-
		AdaRound	✓	75.26	3766	4517
		AdaQuant	✓	75.22	1127	7760
		Bit-split	✓	75.58	5032	10856
		OBQ	✓	75.71	9287	6859
		FastOBQ	✓	75.77	80	3683

classification task, 0.1% of the original training set (approximately 2,048 samples) is randomly sampled to form the calibration dataset, augmented with standard data augmentation techniques (random flipping and cropping) to expand the dataset size by tenfold. For object detection tasks, no data augmentation is applied. Additionally, to ensure numerical stability and invertibility of the Hessian matrix H , a damping value of 0.1 is uniformly added to its diagonal elements. After the quantization process, a post-processing step tunes the Batch Normalization (BN) layers in the model. This step adjusts the running statistics (mean and variance) of BN layers to adapt to the activation distribution resulting from quantized weights, mitigating potential negative impacts on model accuracy. The procedure involves resetting the running statistics of all BN layers, performing several forward passes on the quantized model using the calibration dataset, and re-estimating and updating the running mean and variance of the BN layers. During final evaluation, the model uses these tuned BN statistics, which better reflect the data distribution characteristics after quantization.

6.2 Comparative Experiments

To evaluate the proposed quantization method, experiments compare layer-wise and non-layer-wise approaches on ImageNet and COCO tasks, with results in Tables 1, and 2. On ImageNet, the method matches top methods at 4 bits, out-

Table 2: Comparison of different methods under YOLOv5 model quantization. “Time” denotes quantization times. “Mem.” denotes peak memory usage.

Model	Bit Width	Method	Layer-wise mAP@0.5	mAP@0.5:0.95	Time (s)	Mem. (MB)
	FP32	-	-	37.46	56.73	-
	Bias Correction	✓	26.52	45.69	-	-
YOLOv5s	W6A32	OBQ	✓	37.01	56.46	611
	FastOBQ	✓	36.60	56.25	17	1966
	FP32	-	-	37.46	56.73	-
	Bias Correction	✓	26.95	45.89	-	-
YOLOv5s	W8A32	OBQ	✓	37.41	56.74	766
	FastOBQ	✓	37.36	56.70	22	1966
	FP32	-	-	45.16	63.88	-
	Bias Correction	✓	35.33	53.96	-	-
YOLOv5m	W6A32	OBQ	✓	44.83	63.81	3289
	FastOBQ	✓	44.37	63.44	36	3007
	FP32	-	-	45.16	63.88	-
	Bias Correction	✓	35.56	53.99	-	-
YOLOv5m	W8A32	OBQ	✓	45.09	63.87	3282
	FastOBQ	✓	45.08	63.88	39	3007

performing the non-layer-wise BRECQ with significantly lower quantization time (tens to hundreds of times faster) and minimal resource usage. On COCO, at 6-bit and 8-bit settings, it achieves near-identical accuracy to OBQ (0.3% difference) with hundreds of times faster quantization and reduced resource demands, confirming its effectiveness and efficiency.

6.3 Ablation Studies

Effectiveness of Sensitivity-Guided Parameter Quantization. We conduct experiments on three ResNet models of different scales to validate the effectiveness of the proposed sensitivity-guided parameter quantization. The results are shown in Table 3. To ensure fair comparison, all results based on sensitivity-guided ordering are reproduced under identical settings. For parameter sorting methods in ascending order, the quantized model accuracy significantly decreases, with an average reduction of 0.5% compared to descending order sorting. Among the various parameter sorting methods tested, the sensitivity-based sorting method achieves a slight accuracy advantage under specific ordering rules, comparable to the heuristic OBQ algorithm. These results indicate that the proposed method, by considering parameter sensitivity and leveraging Taylor expansion-based minimization of layer-wise quantization errors for parameter compensation, better accounts for the importance of parameters to be quantized, thereby enhancing the quantization performance.

Effectiveness of Row-Parallel Matrix Parameter Quantization. As shown in Table 3, introducing the row-parallel quantization algorithm results in no sig-

Table 3: Accuracy of different parameter quantization orders on ResNet models.

Bits	Method	Parallel	ResNet-34			ResNet-50			Avg. Acc.
			Accuracy	Time	Memory	Accuracy	Time	Memory	
W4A32	err_des		72.64	13564	7276	75.49	9208	6859	74.07
	err_asc		72.16	13704	7276	75.32	9199	6859	73.74
	w_des		72.63	13502	7276	75.57	9166	6859	74.10
	w_asc		72.04	13140	7276	75.49	9280	6859	73.77
	sensi_des		72.83	13511	7275	75.58	9112	6859	74.21
	sensi_asc		72.24	13138	7275	75.03	9263	6859	73.64
	No Sorting	✓	72.65	90	3842	75.52	70	3683	74.09
	err_des	✓	73.00	100	3842	75.62	79	3683	74.31
	w_des	✓	72.93	90	3842	75.66	77	3683	74.30
	sensi_des	✓	73.12	93	3842	75.67	79	3683	74.40

nificant accuracy loss compared to non-parallel quantization experiments across the sorting methods tested. Moreover, significant improvements are observed in quantization time and memory usage. These results demonstrate that, when performing row-parallel parameter quantization under specified rules, the proposed method accounts for the similarity in quantization order across rows guided by specific metrics, enabling efficient row-parallel quantization and substantially reducing the time and resource consumption of quantization.

7 Conclusions

We propose FastOBQ, a sensitivity-guided post-training quantization algorithm that enhances efficiency while preserving accuracy. By prioritizing high-sensitivity parameters and using row-parallel quantization with a shared Hessian matrix, FastOBQ reduces quantization error and computational overhead. Experiments on ResNet and YOLOv5 show order-of-magnitude speedups with accuracy comparable to state-of-the-art methods. Our approach is extensible to cross-layer and hybrid-precision quantization, potentially matching retraining-based methods. Future work will explore these extensions, particularly for large-scale models.

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