



UNDERGRADUATE THESIS

**ANALYSIS OF SIMAM-EMA HYBRID ATTENTION
MODULE ON RESNET-50 FOR 64×64 PIXEL
RESOLUTION IMAGE CLASSIFICATION**

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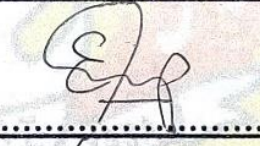
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ABSTRACT

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Attention mechanisms in Convolutional Neural Networks (CNNs) have been shown to improve a model's ability to emphasize important image features. SimAM (Simple, Parameter-Free Attention Module) is an efficient attention mechanism because it computes attention weights without introducing additional parameters; however, it has limited capability in capturing cross-scale spatial information. In contrast, Efficient Multi-Scale Attention (EMA) processes features at multiple scales and models both channel-wise and spatial relationships more comprehensively. These complementary characteristics suggest that SimAM and EMA can be effectively combined. This study investigates a hybrid SimAM–EMA module implemented sequentially within the bottleneck blocks of ResNet-50. Training stability is improved through differential learning rates and freezing the EMA module during the first three epochs to address initialization differences between the pretrained backbone and the newly added EMA layers. Experiments are conducted on the Tiny ImageNet dataset, which contains 200 classes, using Top-1 accuracy, Top-5 accuracy, and computational complexity as evaluation metrics. The results show that the Hybrid SimAM–EMA model achieves 77.84% Top-1 accuracy and 93.44% Top-5 accuracy, outperforming the Baseline ResNet-50 (76.61%), SimAM-Only (76.23%), and EMA-Only (74.18%) models. In terms of computational efficiency, the parameter count increases by only 0.84% (from 23.92M to 24.12M), while GFLOPs increase by 23.2%. Inference latency rises from 7.97 ms to 20.39 ms per image, mainly due to the computational complexity of EMA rather than parameter growth. Despite this overhead, the Hybrid model provides a Top-1 accuracy gain of 1.23% over the baseline and 3.66% over EMA-Only. Ablation analysis confirms that the performance improvement results from the combination of SimAM's feature reweighting capability and EMA's enhanced channel representation learning.

Keywords: Attention Mechanism, EMA, Image Classification, ResNet-50, SimAM, Tiny ImageNet.

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The author realizes that this thesis is not without limitations and shortcomings. Therefore, constructive criticism and suggestions from all parties are sincerely welcomed for the improvement and refinement of this work. Finally, despite all limitations, the author hopes that this thesis will be beneficial to readers in general and to the author in particular.

Surabaya, June 12th 2026

A handwritten signature in black ink, appearing to read 'Iqbal', with a long horizontal flourish extending to the right.

Iqbal Bagus Satriawan

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LIST OF NOTATIONS

e_t^*	:	Energy function for target neuron (t)
t	:	Activation value of the target neuron in the feature map
$\hat{\mu}$:	Mean activation value of neurons within a feature map channel
$\hat{\sigma}^2$:	Variance of neuron activation values within a feature map channel
λ	:	Small regularization constant used to maintain numerical stability and prevent division by excessively small values
\tilde{X}	:	Output feature map after applying the SimAM attention mechanism
X	:	Input feature map from the previous layer in the CNN
E	:	Energy matrix calculated for each neuron using the SimAM energy function
$\frac{1}{E}$:	Inverse energy value used to generate attention weights
$\text{sigmoid}(\cdot)$:	Sigmoid activation function that maps values into the range $([0,1])$ as attention weights
\odot	:	Element-wise multiplication operation between two matrices or tensors
X_i	:	Feature map of the (i)-th group after the channel partitioning process
G	:	Number of channel groups used in the feature grouping mechanism
C	:	Total number of channels in the input feature map
H	:	Height of the feature map

W	:	Width of the feature map
$\frac{C}{G}$:	Number of channels in each group after partitioning
$\mathbb{R}^{C/G \times H \times W}$:	Tensor space representing the dimensions of each grouped feature map
$[X_0, X_1, \dots, X_{G-1}]$:	Operation that divides feature map (X) into (G) channel groups
$x_c(h, i)$:	Activation value in channel (c) at spatial position row (h) and column (i)
$x_c(j, w)$:	Activation value in channel (c) at spatial position row (j) and column (w)
$z_c^H(h)$ and $z_c^W(w)$:	One-dimensional global average pooling output along the horizontal and vertical direction for channel (c)
Σ	:	Summation operation used to calculate the average activation value along a specific dimension
$\frac{1}{W}, \frac{1}{H}$:	Normalization factors used to obtain average values
$x_c(i, j)$:	Activation value in channel (c) at spatial position row (i) and column (j)
z_c	:	Global representation value of channel (c) obtained by averaging all elements in the corresponding channel feature map
i	:	Row index of the feature map
j	:	Column index of the feature map
$error$:	Average classification error on the evaluation dataset
N	:	Total number of image samples in the evaluation dataset

$\frac{1}{N}$:	Normalization factor used to obtain the average error across all samples
$\sum_{i=1}^4 \min_j d_{ij}$:	Sum of the minimum (d_{ij}) values for each index (i) over all indices (j)
d_{ij}	:	Distance or difference value between element (i) and element (j)
$\min_j d_{ij}$:	Minimum value of (d_{ij}) over all indices (j) for a given (i)