UNDERGRADUATE THESIS

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

IQBAL BAGUS SATRIAWAN
NPM 22081010118

THESIS ADVISORS
Dr. Faisal Muttaqin, S.Kom, M.T
Eva Yulia Puspaningrum, S.Kom., M.Kom

MINISTRY OF HIGHER EDUCATION, SCIENCE, AND TECHNOLOGY
UNIVERSITAS PEMBANGUNAN NASIONAL VETERAN JAWA TIMUR
FACULTY OF COMPUTER SCIENCE
INFORMATICS STUDY PROGRAM
SURABAYA
2026

APPROVAL SHEET

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

By:
IQBAL BAGUS SATRIAWAN
NPM. 22081010118

Has been defended before, and accepted by, the Board of Assessors of the Thesis Examination of the Informatics Study Program, Faculty of Computer Science, Universitas Pembangunan Nasional Veteran Jawa Timur, on June 12, 2026:

Approved,

Dr. Faisal Muttaqin, S.Kom, M.T NIP. 19851231 202121 1 009	....	**(Advisor I)**
Eva Yulia Puspaningrum. S.Kom., M.Kom NIP. 19890705 202121 2 002	....	**(Advisor II)**
Eka Prakarsa Mandyartha, S.T., M.Kom NIP. 19880525 201803 1 001	....	**(Head Assessor)**
Hazna At Thooriqoh, S.Tr.Kom., M.Kom. NIP. 19970320 202406 2 003	....	**(Assessor I)**

Acknowledge by,

Dean of the Faculty of Computer Science

Prof. Dr. Ir. Novirina Hendrasarie, MT.
NIP. 19681126 199403 2 001

APPROVAL SHEET

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

By:
IQBAL BAGUS SATRIAWAN
NPM. 22081010118

Approved to proceed to the Thesis Examination

Approved by,

Coordinator of Informatics Study Program
Faculty of Computer Science

Dr. Intan Yuniar Purbasari, S.Kom. MSc.

NIP. 19800602 202521 2 029

STATEMENT OF ORIGINALITY

I am the undersigned:

Student Name	:	Iqbal Bagus Satriawan
NPM	:	22081010118
Degree Program	:	Bachelor (S1)
Study Program	:	Informatics
Faculty	:	Faculty of Computer Science

Hereby declares that this undergraduate thesis contains no part of any other scientific work that has been submitted to obtain an academic degree at any higher education institution. Furthermore, it does not contain any work or opinions previously written or published by others, except for those which are explicitly cited in this thesis and listed completely in references:

And I declare that this scientific document is free from elements of plagiarism. If in the future indications of plagiarism are found in this Thesis, I am willing to accept sanctions in accordance with the applicable laws and regulations.

Thus, I made this statement without any coercion from anyone and to be used as it should.

Surabaya, June 12, 2026
Declarant,

IQBAL BAGUS SATRIAWAN
NPM. 22081010118

ABSTRACT

Student Name / NPM:	:	Iqbal Bagus Satriawan / 22081010118
Thesis Title:	:	Analysis of SimAM-EMA Hybrid Attention Module on ResNet-50 for 64×64 Pixel Resolution Image Classification
Supervisor:	:	1. Dr. Faisal Muttaqin, S.Kom, M.T
	:	2. Eva Yulia Puspaningrum, S.Kom., M.Kom

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.

ACKNOWLEDGEMENTS

Praise be to Allah SWT for all His graces, guidance, and gifts to the author so that the thesis proposal with the title **"Analysis of SimAM-EMA Hybrid Attention Module on ResNet-50 for 64×64 Pixel Resolution Image Classification"** can be completed properly. This thesis is submitted as one of the requirements for obtaining the Bachelor of Informatics (S.Kom.) degree in the Informatics Study Program, Faculty of Computer Science, National Development University "Veteran" East Java. Throughout the process of conducting this research and preparing this thesis, the author received considerable support, assistance, and encouragement in moral, spiritual, and material forms from many individuals and institutions. Therefore, the author would like to express sincere gratitude to:

1. Allah SWT, the Almighty God, for all the blessings, guidance, and strength bestowed upon the author throughout the academic journey and research process.
2. Prof. Dr. Ir. Novirina Hendrasarie, M.T., Dean of the Faculty of Computer Science, Universitas Pembangunan Nasional “Veteran” Jawa Timur.
3. Dr. Intan Yuniar Purbasari, S.Kom., M.Sc., Head of the Informatics Study Program, Faculty of Computer Science, Universitas Pembangunan Nasional “Veteran” Jawa Timur.
4. Dr. Faisal Muttaqin, S.Kom., M.T., the First Thesis Supervisor, who consistently provided guidance, direction, and valuable academic insights, enabling this research to be conducted and completed successfully.
5. Eva Yulia Puspaningrum, S.Kom., M.Kom., the Second Thesis Supervisor, who provided valuable suggestions, constructive feedback, and continuous support throughout the thesis preparation process, contributing significantly to the improvement of this research.
6. Eka Prakarsa Mandyartha, S.T., M.Kom., the head advisor, who devoted time to reviewing this research and provided valuable comments and recommendations for the improvement of this thesis.

7. Hazna At Thooriqoh, S.Tr.Kom., M.Kom., the first advisor, who provided valuable academic suggestions and recommendations that helped enhance the quality of this thesis.
8. Andreas Nugroho Sihananto, S.Kom., M.Kom. and Dina Zatusiva Haq, S.Mat., M.Kom., as the Thesis Coordinators of the Informatics Study Program, for their assistance, coordination, and support throughout the thesis preparation process.
9. All lecturers of the Informatics Study Program who shared their knowledge, insights, and academic experiences during the author's years of study, as well as all administrative and academic staff members who provided assistance in various academic and administrative matters, thereby facilitating the completion of this thesis.
10. The author's beloved parents, Antin Setiowati and Budi Harnowo, who have always been a source of prayers, encouragement, and strength. The author is deeply grateful for their unconditional love, countless sacrifices, and unwavering support, which made it possible to complete this educational journey and thesis.
11. The author's beloved family members, who continuously provided care, prayers, support, and encouragement, enabling the author to persevere throughout the academic journey and successfully complete this thesis.
12. The author's friends, Adhyasta, Dzaky, Eka, Ferry, Jerry, Orie, Samuel, Rifqi, and Wildan, for their assistance, support, companionship, and for helping the author maintain both motivation and sanity throughout this journey.
13. Fellow students and colleagues throughout university life, who became valuable companions in sharing knowledge, experiences, and motivation, while continuously providing support during the preparation of this thesis.
14. Depot Kopivan, which became one of the author's favorite places to study, discuss ideas, and complete various parts of this thesis in a comfortable environment that supported productivity.
15. The author's laptop and internet connection, which faithfully accompanied the entire research process, from literature review and experimental implementation to numerous revisions that ultimately brought this thesis to its completion.

16. Myself. Thank you. Thank you for persevering this far. Thank you for continuing to move forward even when the destination seemed uncertain and the journey ahead was unclear. There were days when motivation was abundant, but there were also days when exhaustion, fear, and doubt arrived all at once. There were moments when everything felt unbearably slow, when the expected results seemed impossible to achieve, and when questions about personal capability became difficult to ignore. Thank you for fighting. Thank you for enduring. And thank you for never giving up.

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

Iqbal Bagus Satriawan

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PSEUDOCODE

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
sigmoid(·)	:	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
$[X_0, X_1, \ldots, X_{G-1}]$	:	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)
$\sum$	:	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)