CERTIFICATE

This is to certify that the thesis entitled "**A Framework for Developing an Enhanced Convolutional Neural Network-Based Ensemble Learning Model for Alzheimer's Disease Classification Using MRI Brain Images**" submitted to the Avinashilingam Institute for Home Science and Higher Education for Woman, Coimbatore, for the award of the degree of **Doctor of Philosophy in Computer Science**, is a record of original research work done by **S. Chithra (18PHCSP007)**, during the period of her study in the Department of Computer Science, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, under my supervision and guidance and the thesis has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or Seminar title to any candidate of any University.

25/3/25

Signature of the

Head of the Department

Dr. B. Kalpana, M.Sc., M.Phil., Ph.D.
Professor and Head
Department of Computer Science
Avinashilingam Institute for Home Science
and Higher Education for Women
(Deemed University), Coimbatore - 641 043

25/3/25

Signature of the Supervisor

Dr.R.VIJAYABHANU, MCA.,M.Phil.,Ph.D.,
Associate Professor
Department of Computer Science
Avinashilingam Institute for Home Science
and Higher Education for Women
Coimbatore-641043

25/03/25

Signature of the Dean

Dr.(Mrs) V. RADHA
Dean, School of Physical Sciences and
Computational Sciences
Professor, Department of Computer Science
Coordinator, B.Voc (AI & ML)
Avinashilingam Institute for Home Science
and Higher Education for Women
Coimbatore - 641 043

DECLARATION

I hereby declare that the thesis titled "**A Framework for Developing an Enhanced Convolutional Neural Network-Based Ensemble Learning Model for Alzheimer's Disease Classification Using MRI Brain Images**" is the result of investigations carried out by me in the Department of Computer Science, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, under the supervision and guidance of **Dr. R.Vijayabhanu**, Associate Professor, Department of Computer Science, Avinashilingam Institute for Home Science and Higher Education for Woman, Coimbatore, and that it has not been submitted for the award of any Degree / Diploma / Associateship / Fellowship or similar title of any University or Institute.

25/3/25

Signature of the Supervisor

Dr.R.VIJAYABHANU, MCA.,M.Phil.,Ph.D.,
Associate Professor
Department of Computer Science
Avinashilingam Institute for Home Science
and Higher Education for Women
Coimbatore-641043

Signature of the Research Scholar

ACKNOWLEDGEMENT

At the outset, I would like to express my sincere gratitude to the God Almighty for his/her constant love, blessing and grace showered on me making my meaningful and worthwhile to the society.

I express my reverential gratitude to ***Late Sri. T.S. Avinashilingam Ayya Avl.,*** Founder and the First Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing this temple of learning for women.

My reverential gratitude to ***Late Dr. (Tmt) Rajammal P. Devadas Amma Avl.,*** M.A., M.Sc., Ph.D. (OHIO State), Hon. D.Sc., Hon D.Sc., Former Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, *for her heavenly blessings*.

I express my gratitude to the ***Late Padma Shri. Dr. P. R. Krishnakumar***, Former Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing me with an opportunity, infrastructure and all the amenities to carry out the research.

I express my heartfelt thanks to Former ***Chancellor Dr. S. P.*** Thyagarajan, D.Sc., M.D., Ph.D., Avinashilingam Institute for Home Science and Higher Education for women, for providing me the moral support for the conduct of research work.

I express heartfelt thanks to ***Chancellor Sri. T.S.K. Meenakshisundaram,*** M.A., M.Phil., Ph.D.,Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing the facilities to conduct the study.

I express my immense gratitude to ***Dr. (Mrs.) Premavathy Vijayan,*** M.Sc., M.Ed., Dip. Spl. Edn. (U.K.), M.Phil., Ph.D., Former Vice Chancellor, Avinashilingam Institute for home science and Higher Education for women for her constant encouragement throughout the research work.

I express my sincere gratitude to ***Dr. (Mrs) V.Bharathi Harishankar*** Ph.D., FRSA, Vice Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing the necessary platform and support for research work.

My sincere thanks to ***Dr. (Mrs) S. Kowsalya,*** M.Sc., M.Phil., Ph.D., Former Registrar, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing the opportunity to do this research.

My sincere thanks to ***Dr. (Mrs) H. Indu,*** **M.Sc (Phy)., M.Ed., SLET (Edn)., Dip in Multimedia., M.Phil (Education)., Ph.D (Education)., M.B.A (Education Management),** Registrar, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing the opportunity to do this research.

I sincerely thank to ***Dr. (Mrs) K. Manimozhi,*** M.Sc., B.Ed. M.Phil., Ph.D., Former Controller of Examination**,** Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for giving suggestions and support to me at all times of need.

I owe deep gratitude to ***Dr. K. Sambath Rani*** *M.R.Sc*, M.Phil., M.Ed, (MR+VI), Ph.D., NET, Controller of Examination**,** Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her constant encouragement, support and wishes.

I record my gratefulness to ***Dr.(Mrs.) P.Lalitha,*** M.Sc., M.Phil., Ph.D., Dean, R&D, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for her timely help, support and encouragement in carrying out the research work.

I am also thankful to ***Dr. (Mrs). K. Udaya Chandrika,*** M.Sc., M.Phil., Ph.D., Former Dean, School of Physical Sciences and Computational Sciences, for granting the facilities required. I am obliged for their extended support throughout my work.

I sincerely thank ***Dr. (Mrs). V. Radha***, M.Sc., B.Ed., PGDOR., PGDCA., M.Phil., Ph.D., Dean, School of Physical Sciences and Computational Sciences, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing her constant encouragement, motivation, and suggestions for my research work.

My thanks are also due to ***Dr. (Mrs.) S.N. Geethalakshmi,*** MCA., M.Phil., Ph.D., Former Professor and Head**,**, Department of Computer Science, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her blessings, support, timely help, encouragement and cooperation rendered towards the completion of this research.

My thanks are also due to ***Dr. (Mrs.) B. Kalpana,*** M.Sc., M.Phil , Ph.D., Professor and Head**,** Department of Computer Science, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her blessings, support, timely help, encouragement and cooperation rendered towards the completion of this research.

My heartfelt and deep sense of gratitude to my beloved supervisor, ***Dr. (Mrs.) R. Vijayabhanu,*** MCA, M.Phil., Ph.D**.,** Associate Professor, Department of Computer Science., who enlivened and gave a golden opportunity to carry out my research on this topic, which helped me a lot to learn many new things. I am very grateful for her continuous guidance with all the useful discussions and brainstorming sessions, especially during the difficult conceptual development stage of my research. She has always been my thriving force and inspiration. Her unwavering enthusiasm for research kept me constantly engaged and fortified my passion for research.

I thank the Doctoral Committee Member ***Dr. M. Punithavalli,*** M.Sc., M.Phil.,Ph.D., Professor and Head, Department of Computer Applications, Bharathiar University, Coimbatore for helping me to fine-tune my research work through her valuable discussions, comments and suggestions.

I am thankful to the Librarians of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for utilizing various e-resources available in our university library. I also thank the technical staff members, who are the helping hands technically to carry out my research work safely and successfully.

I owe a deep sense of gratitude to reviewers, editors, scientists, professors, research forums, publishers, peer-reviewed journals, reputed conferences, workshops and seminars, the research community, resource persons, professionals, research scholars, invited speakers and colleagues for contributing their scientific ideas, knowledge, resources & materials, a precious suggestion which significantly supported me to learn, gain knowledge, and explore my research work to a great extent.

I am so thankful to all research scholars, staff members, Department of Computer Science and members of Computer Center, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for their support, cooperation, suggestions and wishes.

I extend my heartfelt thanks to ***my parents, my husband***, ***daughters,*** and all my family members for their unwavering love, prayers, support, blessings and encouragement throughout this endeavor. I am also grateful to my friends and everyone else who has offered their support and well-wishes along the way. Besides this, I would like to extend my gratitude to one, and all who have knowingly or unknowingly, directly or indirectly help me in the successful completion of this work.

I am also grateful to the Almighty for the blessings throughout the journey which walks me in the correct direction for successful completion of this work.

Chithra S

CHAPTER NO	TITLE	PAGE NO
7	**ENSEMBLE BOOTSTRAP AGGREGATING WITH NEURO EVOLUTION OF AUGMENTING TOPOLOGIES BASED HYBRID TECHNIQUES FOR CLASSIFYING STAGES OF AD**	**105**
	7.1 Introduction	105
	7.2 Classifiers for AD stage classification	105
	7.2.1 Decision Tree (DT)	105
	7.2.2 NEAT classifier	107
	7.2.3 The proposed BAGGING_NEAT classifier	108
	7.3 Experimental result and analysis for BAGGING_NEAT classifier	110
	7.3.1 Result analysis of BAGGING_NEAT classifier on the ADNI dataset	111
	7.3.2 Result analysis of BAGGING_NEAT classifier on the OASIS dataset	114
	7.3.3 Performance comparison of the proposed AlexNet with BAGGING_NEAT method on ADNI and OASIS dataset	118
	7.3.4. Performance comparison of stage-wise analysis of Alzheimer's Detection using the proposed AlexNet with BAGGING_NEAT method on ADNI and OASIS dataset	118
	7.4 Summary	121
8	**CONCLUSION AND FUTURE ENHANCEMENT**	**122**
	8.1 Conclusion	122
	8.2 Future enhancement	127
9	**REFERENCES**	**128**
	ANNEXURES	**143**
	LIST OF PUBLICATIONS	**147**
	PLAGIARISM REPORT	

LIST OF TABLES

Table No	Title	Page No
2.1	Literature survey on recent studies for AD classification	35
2.2	Overview of recent studies related to AD based on the dataset	36
3.1	ADNI dataset description	45
3.2	OASIS-3 Dataset description	47
5.1	Overall Features using GLCM, GLRLM, and GLDM methods	81
5.2	CNN Parameters	88
6.1	Performance comparison of the various classification methods with BAGGINNG_SVM used for AD stage classification on the ADNI dataset	97
6.2	Performance comparison of BAGGING_SVM classification methods with the existing classification methods for AD stage classification on ADNI dataset	98
6.3	Performance comparison of the various classification methods with BAGGING_SVM for AD stage classification on the OASIS dataset	99
6.4	Performance comparison of BAGGING_SVM classification methods with the existing classification methods for AD stage classification on the OASIS dataset.	100
6.5	Performance comparison of AlexNet with BAGGING_SVM on ADNI and OASIS dataset	101
7.1	Performance measures formulas	110
7.2	Performance Metrics with Fused Features (GLCM, GLRLM, and GLDM) with BAGGING_NEAT - k=5 Fold Cross-Validation on ADNI Dataset	111

Table No	Title	Page No
7.3	Performance Metrics with Fused Features (GLCM, GLRLM, and GLDM) with BAGGING_NEAT - k=10 Fold Cross-Validation on ADNI Dataset	112
7.4	Performance comparison of the various classification methods with BAGGING_NEAT for AD stage classification on the ADNI dataset	113
7.5	Performance comparison of BAGGING_NEAT classification method with the existing classification methods for AD stage classification on the ADNI dataset	114
7.6	Performance Metrics of GLCM, GLDM, and GLRLM with BAGGING_NEAT k=5 fold cross-validation on OASIS dataset	115
7.7	Performance Metrics of GLCM, GLDM, and GLRLM with BAGGING_NEAT k=10 fold cross-validation on OASIS dataset	115
7.8	Performance comparison of the various classification methods with BAGGING_NEAT for AD stage classification on OASIS dataset	116
7.9	Performance comparison of BAGGING_NEAT classification method with the existing classification methods for AD stage classification on the OASIS dataset	117
7.10	Performance comparison of AlexNet with BAGGING_NEAT on ADNI and OASIS dataset	118

LIST OF FIGURES

Figure No	Title	Page No
1.1	Anatomy of the human brain	4
1.2	Neuronal anatomy in the human brain	4
1.3	Difference between the normal and AD brain and its components	8
1.4	MRI of human brain with CN	10
1.5	MRI of human brain with MCI	10
1.6	MRI of human brain with AD	11
1.7	Basic Architecture of Convolutional Neural Network	15
3.1	Overview of the Research Methodology for AD Classification	40
3.2	AlexNet Architecture	43
3.3	ADNI dataset samples	46
3.4	OASIS dataset samples	48
4.1	Denoised brain neuron MR images using the Weiner filter on ADNI and OASIS Datasets	51
4.2	Denoised brain neuron MR images using the Weighted Median filter on ADNI and OASIS Datasets	53
4.3	Denoised brain neuron MR images using the Adaptive filter on ADNI and OASIS Datasets	54
4.4	Denoised brain neuron MR images using the Hampel identifier filter on ADNI and OASIS Datasets	55
4.5	Denoised brain neuron MR images using the proposed hybrid AFHI method filter on ADNI and OASIS Datasets	57

Figure No	Title	Page No
4.6	(a) Original noisy image (b) Denoised image with stage 3 by proposed hybrid AFHI method on ADNI Dataset	58
4.7	(a) Original noisy image (b) De-noised image with stage 3 by proposed hybrid AFHI method on OASIS Dataset	58
4.8	RMSE Performance measure analysis of filtering methods for ADNI and OASIS datasets	64
4.9	PSNR Performance measure analysis of Filtering methods for ADNI and OASIS datasets	60
4.10	Performance measure analysis of filtering methods for ADNI and OASIS datasets	61
4.11	Proposed architecture for segmentation	62
4.12	DWT processing structure	66
4.13	Comparison of denoised brain neuron MR images using ADNI Datasets	70
4.14	Comparison of denoised brain neuron MR images using OASIS Datasets	71
4.15	RMSE Performance measure analysis of segmentation methods for ADNI and OASIS datasets	72
4.16	PSNR Performance measure analysis of segmentation methods for ADNI and OASIS datasets	73
4.17	MAE Performance measure analysis of segmentation methods for ADNI and OASIS datasets	73
5.1	Brain MRI of (a) an AD patient (b) a healthy individual after feature extraction	80
5.2	Overall working mechanism for traditional feature extraction techniques	81
5.3	CNN transfer learning model	83
5.4	Dropout layers architecture	84

Figure No	Title	Page No
5.5	AlexNet Layers	86
5.6	Overall structure of the proposed approach using CNN for feature extraction	89
6.1	Stage wise accuracy analysis of classification using AlexNet with BAGGING_SVM on ADNI and OASIS datasets	102
6.2	Confusion matrix for AlexNet with BAGGING_SVM using ADNI dataset	103
6.3	Confusion matrix for AlexNet with BAGGING_SVM using OASIS dataset	104
7.1	Stage wise accuracy analysis of classification using AlexNet with BAGGING_NEAT on ADNI and OASIS datasets	119
7.2	Confusion matrix for AlexNet with BAGGING_NEAT using ADNI dataset	120
7.3	Confusion matrix for AlexNet with BAGGING_NEAT using OASIS dataset	121

ACRONYMS

AD	Alzheimer's Disease
ADNI	Alzheimer's Disease NeuroImaging Initiative
AFHI	Adaptive Filter Hampel Identifier
BAGGING	Bootstrap Aggregating
CN	Cognitively Normal
CNN	Convolutional Neural Network
CT	Computer Tomography
DL	Deep Learning
DT	Decision Tree
DWT	Discrete Wavelet Transform
ELM	Extreme Learning Model
GANs	Generative Adversarial Networks
GLCM	Gray-Level Co-occurrence Matrix
GLDM	Gray Level Dependence Matrix
GLRLM	Gray Level Run- Length Matrix
KNN	K- Nearest Neighbour
LH,HH	High Pass
LL, HL	Low Pass
LRN	Local Response Normalization
LSTM	Long Short-Term Memory

MAE	Mean Absolute Error
MCI	Mild Cognitive Impairment
ML	Machine Learning
MRI	Magnetic Resonance Imaging
NEAT	Neuro Evolution of Augmenting Topologies
NN	Neural Network
OASIS	Organization for the Advancement of Information Standards
PET	Positron Emission Tomography
PSNR	Peak Signal-to-Noise Ratio
ReLU	Rectified Linear Unit
RG	Region Growing
RMSE	Root Mean Squared Error
RNN	Recurrent Neural Network
SPECT	Single Photon Emission Computerized Tomography
SSIM	Structural Similarity Index Measure
SVM	Support Vector Machine