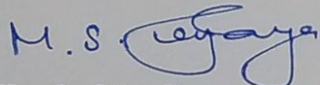


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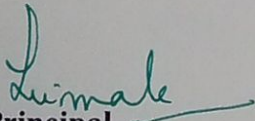
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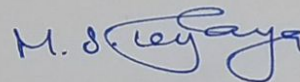
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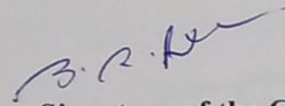


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DECLARATION

I, **B.R. Laxmi Sree** hereby declare that the thesis, entitled "**GRAPH BASED SEGMENTATION AND DEEP LEARNING FOR PHONEME PATTERN CLASSIFICATION IN TAMIL CONTINUOUS SPEECH**" submitted to Bharathiar University, in partial fulfillment of the requirements for the award of the **Degree of Doctor of Philosophy in Computer Science** is a record of original and independent research work done by me during January 2012 to September 2019 under the Supervision and Guidance of **Dr. (Mrs.) M. S. Vijaya**, M.Sc., M.Phil., Ph.D, Associate Professor and Head, Department of Computer Science at PSGR Krishnammal College for Women, Coimbatore and it has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or other similar title to any candidate in any university.

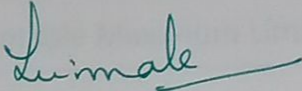


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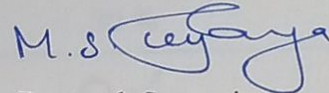
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LIST OF ABBREVIATIONS

2D	-	Two Dimensional
AI	-	Artificial Intelligence
ANFIS	-	Adaptive Neuro-Fuzzy Inference System
ANN	-	Artificial Neural Network
ATIS	-	Airline Travel Information System
AUC	-	Area Under Curve
BBDBN	-	Bernoulli - Bernoulli DBN
BSNLF	-	Blind Segmentation using Non-linear filters
CART	-	Classification and Regression Trees
CD	-	Context Dependent
CD-DBN	-	Deep Belief Networks pretrained with Contrastive Divergence
C-MMSE	-	Cepstral-Minimum Mean Squared Error
CMU	-	Carnegie Mellon University
CSR	-	Continuous Speech Recognition
CT	-	Computed Tomography
CWT	-	Continuous Wavelet Transform
DBN	-	Deep Belief Network
DNN-HMM	-	Deep Neural Network – Hidden Markov Model
DP	-	Deleted Phonemes
DTW	-	Dynamic Time Warping
DWT	-	Discrete Wavelet Transform
DWTFS	-	Discrete Wavelet Transform Feature Set
EIS	-	Evolving Intelligent System
EP	-	Expected number of Phonemes
ESPNet	-	Self Evolving and Parameter adaptation Network
FFT	-	Fast Fourier Transform
FIR	-	Finitive Impulse Response

FN	-	False Negatives
FNN	-	Fuzzy Neural Network
FOS	-	Factor of Safety
FP	-	False Positives
GBDBN	-	Gaussian - Bernoulli DBN
GD	-	Gradient Descent
GMM	-	Gaussian Mixture Model
GPU	-	Graphical Processing Unit
HFCC-E	-	Human Factor Cepstral Co-efficients – Equivalent Rectangular Bandwidth
HMM	-	Hidden Markov Model
ID3	-	Iterative Dichotomiser 3
IIR	-	Infinite Impulse Response
IL	-	Indian Languages
IP	-	Inserted Phonemes
K-nn	-	K-Nearest Neighbour
LDA	-	Linear Discriminant Analysis
LDC	-	Linguistic Data Consortium
LFB	-	Low Frequency Band
LFCC	-	Linear Frequency Cepstral Co-efficients
LPC	-	Linear Predictive Coding
LSTM	-	Long Short Term Memory
LVCSR	-	Large Vocabulary Continuous Speech Recognition
LVSR	-	Large Vocabulary Speech Recognition
MC	-	Mis-Classified Phonemes
McSLM	-	Metacognitive Scaffolding Learning machine
MDR	-	Multimedia Document Recognition
MFCC	-	Mel- Frequency Cepstral Co-efficients
MLP	-	Multi Layer Perceptron

MMF	-	Maximum Mutual Information
MMI	-	Maximum Mutual Information
MRI	-	Magnetic Resonance Imaging
MSE	-	Mean Square Error
MWP-ACE	-	Mixed Wavelet Packet Advanced Combinational Encoder
NLP	-	Natural Language Processing
NMPSO	-	New Method Particle Swarm Optimization
NN	-	Neural Network
NUSDWT	-	Non-uniform segmentation using DWT
PCA	-	Principle Component Analysis
pClass+	-	Parsimonious Classifier+
PER	-	Phoneme Error Rate
PLP	-	Perceptual Linear Prediction
PSO	-	Particle Swarm Optimization
RAST	-	Rapid Annotation using Subsystem Technology
RBM	-	Restricted Boltzmann Machine
ReLU	-	Rectified Linear Unit
RIVMcSLM	-	Recurrent Interval-Valued McSLM
RM	-	Resource Management
RMSE	-	Root Mean Square Error
RNN	-	Recurrent Neural Network
ROC	-	Receiver-Operating Characteristic Curve
SBC	-	Subband based Cepstral Parameter
SCARF	-	Segmental Conditional Random Fields
SGPSO	-	Second Generation Particle Swarm Optimization
SMOTE	-	Synthetic minority over-sampling technique
ST2Class	-	Scaffolding Type-2 classifier
STFT	-	Short Term Fourier Transform

SVM	-	Support Vector Machine
TI	-	Texas Instruments
TN	-	True Negatives
TP	-	True Positives
TPSO	-	Temperature controlled Particle Swarm Optimization
VAD	-	Voice activity detection
VE	-	Voting Expert
VOP	-	Vowel Onset Point
WER	-	Word Error Rate
WMSE	-	Weighted Mean Square Error

LIST OF SYMBOLS

θ	-	Phase spectrum
ω	-	Phase shift
τ	-	Group delay function
S	-	Speech signal
$s(n)$	-	da
ϕ	-	Wavelet function
m	-	Resolution level while applying wavelet transform
\mathbb{G}	-	Graph (Multigraph)
\mathbb{V}	-	Set of vertices of graph G
\mathbb{E}	-	Set of edges of graph G
$cut()$	-	Degree of dissimilarity between two graphs
$w(u,v)$	-	Similarity between two nodes u and v in a Graph/weight of edge (u,v)
$Ncut()$	-	Normalized cut – measure of disassociation between two subgraphs
$assoc()$	-	Measure of association between two subgraphs
$Nassoc()$	-	Measure of normalized association between two subgraphs
F	-	Set of feature vectors of speech S
ζ	-	Distance factor/node distance
W	-	Weight matrix of graph
D	-	Diagonal matrix where each d_i represents the total weight i^{th} node
ε_i	-	i^{th} value in the sorted list of eigenvalues
E_i	-	i^{th} eigen vector

Y	-	Filtered speech
b_0, b_1, b_2	-	Co-efficients of second order filter
db2	-	Daubachies wavelet
θ	-	Model parameters
V	-	Number of visible nodes in RBM
H	-	Number of hidden nodes in RBM
$E()$	-	Energy function of neurons
w_{ij}	-	Connection weight between i^{th} node in visible layer to j^{th} node in hidden layer of an RBM
b_i	-	Bias of i^{th} visible neuron
a_j	-	Bias of j^{th} hidden neuron
\mathcal{N}	-	Gaussian function
$p()$	-	Conditional probability distribution
Δw_{ij}	-	Change in weight parameter for connection between i^{th} visible node and j^{th} hidden node
$\langle v_i h_j \rangle_{td}$	-	Measured frequency of visible units for given training data
$\langle v_i h_j \rangle_{rd}$	-	Measured frequency of visible units with reconstructed data
Σ	-	Sigmoid function
x_i	-	Position of i^{th} particle in PSO
M	-	Population size in PSO
T	-	Time/iteration in PSO
$v_i(t)$	-	Velocity of i^{th} particle at time t in PSO
p_g	-	Global position in PSO
r_1, r_2, r_3	-	Uniformly distributed random variables in PSO

c_1	-	Local acceleration co-efficient
c_2	-	Global acceleration co-efficient
ω	-	Inertia weight
v_{min}	-	Lower limit for velocity of particles in PSO
v_{max}	-	Upper limit for velocity of particles in PSO
\bar{P}	-	Geometric centre of the particle swarm
T	-	Time frequency
c_3	-	Geometric centre acceleration co-efficient
ω_1	-	Initial inertia
ω_2	-	Final inertia
MAXITER	-	Maximum number of iterations in PSO
Iter	-	Current iteration in PSO
h()	-	Temperature function
T_{min}	-	Lower bound vector of decision variables in PSO
T_{max}	-	Upper bound vector of decision variables in PSO
P	-	Population in PSO
L	-	Depth of DBN/Number of layers in DBN
L-1	-	Number of RBMs forming DBN
W_i	-	Connection weight of i^{th} RBM
B_i	-	Biases of hidden layer of i^{th} RBM
N_i	-	Number of neurons in i^{th} layer of DBN
\mathbb{N}_i	-	DBN built using i^{th} particle in the population
R	-	RBM
q	-	Number of decision parameters in PSO

n_i	-	Number of biases in i^{th} layer
C	-	Number of output classes
α_i^{\ddagger}	-	Desired output
y_i^{\ddagger}	-	Observed output
m	-	Number of training samples
δ	-	Error
Γ	-	Learning rate
β_n	-	Influence term of n^{th} class
\mathbb{C}_n	-	Number of instances of class n in training dataset
I	-	Total number of instances in training dataset
O	-	Sequence of observations
w_i	-	i^{th} word
$P(w_i)$	-	Prior probabilities
$P(O w_i)$	-	Likelihood
B_i	-	Co-efficients of hyperplane
X_i	-	Variables or datapoints of hyperplane
$K(x, X^i)$	-	Kernel function on input vector x and support vector X^i
gamma	-	Influence of individual sample
$P_{\nu} p(l)$	-	Probability of i^{th} class