

**INTEGRATED WEBSITE USABILITY EVALUATION MODEL USING FUZZY
ANALYTICAL HIERARCHY PROCESS AND ARTIFICIAL NEURAL NETWORK**

BY

**ADEPOJU, Solomon Adelowo
PhD/SICT/2016/852**

**DEPARTMENT OF COMPUTER SCIENCE
FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA**

MAY, 2021

**INTEGRATED WEBSITE USABILITY EVALUATION MODEL USING FUZZY
ANALYTICAL HIERARCHY PROCESS AND ARTIFICIAL NEURAL NETWORK**

BY

**ADEPOJU, Solomon Adelowo
PhD/SICT/2016/852**

**A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL
UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF
PHILOSOPHY (PhD) IN COMPUTER SCIENCE**

MAY, 2021

ABSTRACT

Numerous websites in this contemporary time have been plagued with many usability issues which have hitherto made the websites not effective and efficient for users while searching for information. Consequently, different website usability evaluation models have been proposed to help in evaluating websites. However, most existing models are rather too ambiguous and not easy to use. Also, selecting and ranking websites based on usability with respect to numerous criteria have become a very important decision-making process among users. Additionally, there is no existing machine learning model developed to classify websites usability based on user's rating due to lack of usability ratings data. This thesis therefore proposes a new integrated usability evaluation model using Fuzzy Analytical Hierarchy Process (FAHP) with Artificial Neural Network (ANN). Five criteria of Speed (S_{pd}), Navigation (N_{av}), Ease-of-use (E_{ou}), Content (C_{on}) and Aesthetic (A_{es}) obtained through factor extraction out of initial seven criteria proposed are used in the study. Six Nigerian universities websites with good webometrics ranking are used as alternatives. These are University of Ibadan (UI), Covenant University (CU), Obafemi Awolowo University (OAU), University of Nigeria Nsukka (UNN), University of Lagos (UNILAG) and Ahmadu Bello University (ABU) websites. Two sets of usability data were collected via google forms from 233 and 169 participants. Results from FAHP indicates that UI website has the highest global priority weight and hence is ranked as number one. This is followed by CU, OAU, UNILAG, UNN and ABU websites respectively. Also, final criteria weights obtained are $0.321S_{pd}$, $0.208N_{av}$, $0.197E_{ou}$, $0.166C_{on}$ and $0.108A_{es}$ respectively. This implies that the first and most important criteria to website users is speed. Weights obtained from FAHP model were preprocessed and used to train six machine learning algorithms which are Artificial Neural network (ANN), Random Forest (RF), Decision Tree (J48), Simple Logistic regression (SLOG), Bayesian Network (BaNET) and Logistic Model Tree (LMT). Results show that ANN has the best overall performance with accuracy (A_{cc}) of 93.36% while RF, LMT, SLOG, J48 and BaNET have 90.12% A_{cc} , 88.09% A_{cc} , 88.18% A_{cc} , 88.18% A_{cc} and 83.63% A_{cc} respectively. The FAHP model is further integrated with ANN to classify the user's websites usability ratings. The ANN structure is 5-3-1 with logsig and trainbr as activation and transfer functions respectively. The best performance was obtained at learning rate (l) of 0.8, momentum (m) of 0.9 and threshold value(h) of 0.59. Further results obtained shows a precision (P_{re}), recall (R_{ec}) and F-measure (F_{me}) values of 98.44% P_{re} and 95.45% R_{ec} and 0.96 F_{me} respectively. It is recommended that this integrated model, which can be used for users' websites usability evaluation, ranking and prediction be adopted by IT practitioners and web developers.

TABLE OF CONTENTS

	Page
Cover Page	i
Title Page	ii
Declaration	iii
Certification	iv
Acknowledgements	v-vi
Abstract	vii
Table of Contents	viii
List of Tables	xiv-xv
List of Figures	xvi-xviii
List of Plates	xix-xx
Abbreviations	xxi

CHAPTER ONE: INTRODUCTION

1.1	Background to the Study	1
1.2	Statement of the Problem	7
1.3	Aim and Objectives of the Study	8
1.4	Significance of the Study	8
1.5	Scope and Limitation of the Study	9

CHAPTER TWO: LITERATURE REVIEW

2.1	Introduction to Web Usability	11
2.1.1	Attributes of usability	12

2.1.2	Website usability models	13
2.2	Website Usability Evaluation	15
2.2.1	Empirical usability evaluation methods	17
2.2.1.1	Usability testing	17
2.2.1.2	Expert or inspection-based evaluation method	18
2.2.1.3	Tool based evaluation method	18
2.2.1.4	Soft computing methods	19
2.3	Multi-Criteria Decision Making	19
2.3.1	Classification of MCDM methods	21
2.3.1.1	Analytical hierarchy process (AHP)	22
2.3.1.2	Technique for order of preference by similarity to ideal solution (TOPSIS)	24
2.3.1.3	Elimination and choice expressing reality (ELECTRE)	25
2.3.1.4	Analytic network process (ANP)	25
2.3.1.5	Decision making trial and evaluation laboratory (DEMATEL)	26
2.4	Fuzzy System	26
2.4.1	Fuzzy analytical hierarchy process	29
2.4.1.1	Van Laarhoven and Pedrycz's fuzzy priority approach	30
2.4.1.2	Buckley fuzzy priority method	32
2.4.1.3	Chang extent analysis method	36
2.4.1.4	Chang's entropy-based fuzzy AHP	37
2.5	Data Mining Algorithms and Classification Models	39
2.5.1	Artificial Neural Network (ANN)	42
2.5.1.1	ANN Weights and Biases	46

2.5.1.2	ANN activation functions	45
2.5.1.3	Epoch	46
2.5.2	Bayesian Classifiers	47
2.5.3	Decision Tree Algorithms	49
2.5.4	Simple Logistic Regression	50
2.5.5	Logistic Model Tree (LMT)	51
2.5.6	Random Forest	53
2.6	Related Works on MCDM Approach in Website Evaluation	54
2.6.1	MCDM approach in website evaluation	55
2.6.1.1	MCDM approach in educational website evaluation	55
2.6.1.2	MCDM approach in e-commerce website evaluation	47
2.6.1.3	MCDM approach in e-government website evaluation	60
2.6.1.4.	MCDM approach in travel website evaluation	61
2.6.1.5	MCDM approach in evaluation of other websites genre	62

CHAPTER THREE: RESEARCH METHODOLOGY

3.1	Research Design	70
3.2	Identification of Website Usability Criteria	71
3.2.1	Selection of university websites	72
3.2.3	Usability testing task and evaluation	78
3.2.4	Population and sample of the study	79
3.2.5	Selection of criteria	80
3.3	Development of Fuzzy AHP Model	80

3.3.1	Data transformation	87
3.3.2	Triangular fuzzy numbers (tfns) and fuzzy AHP	88
3.3.3.	Pairwise comparison matrix	91
3.3.4.	Computation of the criteria local weight	92
3.3.5.	Computation of the priority weight and weight aggregation	94
3.4	Data Preprocessing	94
3.4.1.1	Data cleansing	94
3.4.1.2	Data normalization	95
3.4.1.3	Data transformation	95
3.4.1.4	Data reduction	95
3.5	Comparison of Machine Learning Algorithms	96
3.6	Integration with Artificial Neural Network	97
3.6.1	Multi-Layer perceptron neural network	98
3.6.2	Thresholding Algorithm	101
3.6	Model Implementation	102
3.7	Model Performance Evaluation	102
3.7.1	Fuzzy AHP model performance analysis evaluation	102
3.7.2	Machine learning algorithm performance analysis evaluation	103
3.7.2.1	Confusion matrix	104
3.7.2.2	Receiver Operating Characteristic curve	106

CHAPTER FOUR:

RESULTS AND DISCUSSION

4.1	Data Analysis	107
4.1.1	Criteria extraction	108
4.1.2	Extraction and rotation of factor with interpretation	109
4.1.3	Reliability analysis of the derived criteria	111
4.3	Fuzzy AHP Model results	113
4.3.1	Fuzzy AHP model performance evaluation	123
4.4	Website Usability Rating Classification Results	126
4.4.1	Artificial neural network results	126
4.4.2	Bayesian Network results	127
4.4.3	Decision tree results	128
4.4.4	Logistic model tree results	130
4.4.5	Simple logistic regression results	131
4.4.6	Random Forest results	132
4.5	Comparison among Machine Learning Algorithms	133
4.6	Integration with ANN Results	135
4.6.1	Website Usability user rating model formulation	141

CHAPTER FIVE SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1	Summary	143
5.2	Conclusion	144
5.3	Recommendations	145
5.4	Suggestions for Future Research	145

5.5.	Contributions to Knowledge	146
REFERENCES		147
APPENDIX A	Publications	167
APPENDIX B	Questionnaire for phase one of the study	167
APPENDIX C	Questionnaire for phase two of the study	170
APPENDIX D	Component and correlation matrices	177-180
APPENDIX E	Sample data	179-186

LIST OF TABLES

Table	Title	Page
2.1	Website usability Evaluation model	15
2.2	A variant of Saaty Scale	29
2.3	Membership functions of fuzzy numbers	30
2.4	ANN Operational steps	46
2.5	Steps to Build Bayes Net	48
2.6.	Decision tree Algorithm	50
2.7	LogitBoost Algorithm	53
2.8	Random Forest procedure	54
2.9	Distribution Based on MCDM approaches	65
2.10	Criteria used in previous website quality evaluation studies	66-67
2.11	Criteria used in previous website usability evaluation studies	68
3.1	Ranking of Selected University Websites on Webometric	73
3.2	Website usability evaluation model stages	81
3.3	Linguistic variable for Criteria Preference	82
3.4	Linguistic variable for Alternative Preference	83
3.5	Stages of Data Transformation for websites alternatives	87
3.6	Stages of Data Transformation for usability criteria	88
3.7	Fuzzy AHP Algorithm for Criteria Weight computation	93
3.8	Fuzzy AHP Algorithm for Alternative Weight Computation	93
3.9	Fuzzy AHP Algorithm for Overall Priority Alternative Weights	94
3.10	Thresholding Algorithm	102
3.11	Performance Table	103

3.12	Confusion Matrix	104
4.1	Demographic data of the participants	107
4.2	KMO and Bartlett's Test	108
4.3	KMO acceptability values interpretation	109
4.4	Cronbach Alpha value of the criteria	111
4.5.	Cronbach Alpha value interpretation	111
4.6	Demographic data of participants	113
4.7	Criteria Pairwise Comparison matrix for a user	114
4.8.	Alternative Pairwise Comparison matrix for a user	114
4.9	Criteria Comparison Matrix	114
4.10	Geometric Mean Computation	115
4.11	Fuzzy criteria Weight Value	115
4.12	Crisp and Normalised weight values	115
4.13	Overall local weight for the Criteria	116
4.14	Weight of each Alternative website based on each Criteria	117
4.15	Final priority weight of the alternatives	119
4.16	AHP Results	123
4.17	Wilcoxon Signed Rank Test on fuzzy AHP and AHP on criteria weight	123
4.18	Wilcoxon Signed Rank Test on fuzzy AHP and AHP on alternatives websites weight	125
4.19	Overall results of different machine learning algorithms	133
4.20	Threshold values and model performance on the testing dataset	139
4.21	Overall performance analysis of the integrated ANN model	140
4.22	Roots of model equation	141

LIST OF FIGURES

Figure	Title	Page
2.1	MCDM Phases	21
2.2	MCDM Classification	22
2.3	Hierarchical Model of AHP	23
2.4	Analytical Hierarchy Process steps	24
2.5	Crisp and Fuzzy Set	28
2.6	Intersection between M1 and M2	36
2.7	Data mining methods	41
2.8	Artificial Neural Network Structure	43
2.9	Activation function	44
2.10	Bayesian Network	47
2.11	Sigmoid function graph	51
3.1	Research Methodology of the Study	70
3.2	Phase One Methodological Steps	72
3.3	Home page of University of Ibadan website	74
3.4	Home page of Covenant University website	74
3.5	Home page of Obafemi Awolowo University website	75
3.6	Home page of University of Lagos website	75
3.7	Home page of Ahmadu Bello University website	76
3.8	Home page of University of Nigeria website	76
3.9	Initial Schematic structure for phase 1	78

3.10	Fuzzy AHP Model	84
3.11	Phase Two Methodological Procedure	85
3.12	Membership function of triangular fuzzy number	89
3.13	Linguistic variables for the Criteria Comparison	90
3.14	Classification Model Performance Evaluation	97
3.14	ANN model Architecture	99
4.1	Scree Plot	110
4.2	SNECA website usability model	113
4.3	Overall ranking of the alternative websites	119
4.4	Fuzzy AHP ranking of alternative websites wrt speed	120
4.5	Fuzzy AHP ranking of alternative websites wrt navigation	120
4.6	Fuzzy AHP ranking of alternative websites wrt ease of use	121
4.7	Fuzzy AHP ranking of alternative websites wrt content	121
4.8	Fuzzy AHP ranking of alternative websites wrt aesthetic	122
4.9	Overall ranking of the alternative websites wrt to each criteria	122
4.10	Comparative analyses of AHP and FAHP Results	122
4.11	ANN confusion matrix	127
4.12	BaNet confusion matrix	128
4.13	Decision tree confusion matrix	129
4.14	LMT confusion matrix	130
4.15	SLOG confusion matrix	131
4.16	RF confusion matrix	132
4.17	Performance comparison of machine learning algorithms	134
4.18	RMSE comparison of machine algorithms	135

4.19	Integrated ANN model network architecture	136
4.20	Integrated ANN model performance graph	137
4.21	ANN rates of training and testing on testing dataset	137
4.22	Plot of average accuracy against threshold value	138
4.23	Receiver operation characteristic curve	141

LIST OF PLATES

Plate	Title	Page
1.	User testing session one in university ITS SMART laboratory	86
2.	User testing session two in university ITS SMART laboratory	86

ABBREVIATIONS

ACSI:	American Customer Satisfaction Index
AHP:	Analytical Hierarchy process
ANN:	Artificial Neural Network
ANP:	Analytical Network Process
ARTF	Attribute Relation File Format
AUC	Area Under Curve
BaNET:	Bayesian Network
CP:	Comparison Matrix
CSV	Comma Separated value
DEMATEL	Decision Making Trial and Selection Laboratory
ELECTRE:	Et Choix Traduisant la Réalité or Elimination and Choice Translating Reality
EON:	Ease of Navigation
EOU:	Ease of Use
EUM	Enhanced Usability Model
IEEE	Institute of Electrical and Electronics Engineers
ISO:	International Standard Organisation
LMT:	Linear Model Tree
LWM:	Linear Weighted Method
MAUT	Multi Attribute Utility Theory
MCDA;	Multi-Criteria Decision Analysis
MCDM:	Multi-Criteria Decision Making
MODM	Multi-Objective Decision Making

NHM:	New Hybrid Model
NIS	Negative Ideal Solution
OR	Operation Research
PCM:	Pairwise Comparison Matrix
PIS	Positive Ideal Solution
PROMETHEE:	Preference Ranking Organization METHod for Enrichment Evaluations
QFD:	Quality Function Deployment
QUIM	Quality in Use Model
RF:	Random Forest
RT:	Response Time
SLOG:	Simple Logistic Model Tree
TOPSIS:	Technique for Order of Preference by Similarity to Ideal Solution
UE	Usability Evaluation
UE:	Usability Evaluation
UMM	Usability Measurement Model
VIKOR	Vlse Kriterijumska Optimizacija I Kompromisno Resenje
WDBA:	Weighted Distance Based Approximation
WUE:	Website Usability Evaluation
WUEM	Web Usability Evaluation Model
WVA	Wavelength Variant Analysis