A FRAMEWORK FOR INTELLIGENT VOICE-ENABLED E-EDUCATION SYSTEMS

BY

AZETA, Agbon Ambrose
(CUGP050134)

A THESIS
SUBMITTED TO THE DEPARTMENT OF COMPUTER AND INFORMATION SCIENCES,
SCHOOL OF NATURAL AND APPLIED SCIENCES, COLLEGE OF SCIENCE AND TECHNOLOGY, COVENANT UNIVERSITY,
OTA, OGUN STATE NIGERIA,

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF

DOCTOR OF PHILOSOPHY

IN

COMPUTER SCIENCE

MARCH, 2012

CERTIFICATION

This is to certify that this thesis is an original research work undertaken by Ambrose Agbon Azeta with matriculation number CUGP050134 under our supervision and approved by:

Professor Charles Korede Ayo ----------
Supervisor Signature and Date

Dr. Aderemi Aaron Anthony Atayero ----------
Co- Supervisor Signature and Date

Professor Charles Korede Ayo ----------
Head of Department Signature and Date

External Examiner Signature and Date

DECLARATION

It is hereby declared that this research was undertaken by Ambrose Agbon Azeta. The thesis is based on his original study in the department of Computer and Information Sciences, College of Science and Technology, Covenant University, Ota, under the supervision of Prof. C. K. Ayo and Dr. A. A. Atayero. Ideas and views of this research work are products of the original research undertaken by Ambrose Agbon Azeta and the views of other researchers have been duly expressed and acknowledged.

Professor Charles Korede Ayo ----------

Supervisor Signature and Date

Dr. Aderemi Aaron Anthony Atayero ----------

Co- Supervisor Signature and Date

ACKNOWLEDGMENTS

I wish to express my thanks to God almighty, the author of life and provider of wisdom, understanding and knowledge for seeing me through my Doctoral research program. My high appreciation goes to the Chancellor, Dr. David Oyedepo and members of the Board of Regent of Covenant University for catching the vision and mission of Covenant University. My thanks also goes to the Management of Covenant University: the Vice Chancellor, the Registrar, the Deans of the Colleges, the Heads of Department for driving the vision towards attaining excellence and sound academic program.

I am also greatly thankful to my supervisors Professor C. K. Ayo and Dr. A. A. Atayero for their immense support and guidance throughout the course of this research. I am grateful to them for introducing me to an interesting area of speech technology that I enjoyed working on. Despite their extremely busy schedules, I received complete attention and timely guidance that helped me to complete this thesis.

I thank the members of Automated Speech Recognition for Customer Relationship Management (ASR4CRM) research team - Professor C. K. Ayo, Dr. A. A. Atayero and Dr. N. A. Ikhu-Omoregbe, whose inputs and suggestions helped me to advance in this study from the very foundation of this research to its completion. My thanks also goes to Professor E. F. Adebiyi for his words of encouragement and support for the work. I would like to thank my colleague Dr. J. O. Daramola for giving me important suggestions and insight on my work. I have learned immensely during the course of my interaction with him. My appreciation goes to Dr. N. A. Ikhu-Omoregbe and Dr. J. O. Daramola for making their thesis available for other researchers including myself to use as a guideline for thesis writing. I thank the Dean of Post Graduate School, Professor C. O. Awonuga and all my teachers at the postgraduate school.

Special thanks goes to my elder brother- Mr. Victor Azeta, my siblings, my parents (especially my father Mr. P. U. Azeta) who kept encouraging me to push on and complete the research. I dedicate this thesis to my dad. I will not forget my loving wife Mrs A. E. Azeta and my four beautiful children: Joy, Emmanuel, David and Daniel whose unending love and support sustained and encouraged me throughout the Ph.D program. I would not have been able to embark on this journey without their home support. I am also particularly grateful for the invaluable suggestions and insight I received from members of the Department of Computer

and Information Sciences (CIS), particularly the Software Engineering and Intelligent System (SEIS) unit for their constructive comments during the several presentations of the work. May God bless you all.

Special thanks also goes to Voxeo Inc. for freely hosting the prototype version of the voice application.

TABLE OF CONTENTS **PAGE**

Title Page……i
Certification……ii
Dedication……...iii
Declaration……..iv
Acknowledgments……...v
List of Figures ……ix
List of Tables ……...xi
Abstract……xii

CHAPTER ONE

1.0 INTRODUCTION…….....1
1.1 Background Information…….....1
1.2 Motivation for the study…….....3
1.3 Statement of the Problem…….....6
1.4 Aim and Objectives of the study…….....8
1.5 Research Methodology…….....9
1.6 Significance of the Study…….....11
1.7 Contribution to Knowledge……...12
1.8 Limitations of the Study…….....12
1.9 Glossary of Terms and Definitions...……13
1.10 Structure of the Thesis…….....15
1.11 Summary ……...15

CHAPTER TWO

2.0 REVIEW OF RELEVANT LITERATURE…….....16
2.1 Introduction……16
2.2 AI Concepts and Terminologies…….....16
2.2.1 Case-Based Reasoning…….....17
2.2.2 Information Retriever……....17
2.2.3 Stemming Algorithm……18
2.2.4 Vocabularies and Ontologies ……..19
2.3 The Generations of Web Technology……....19

2.4 E-Education Technologies ……...21
2.5 Assistive Technology ……..…..22
2.6 Voice Interfaces ……24
2.7 Voice-Enabled Web Paradigm ……26
2.7.1 Voice Portals ……26
2.7.2 Voice Servers ……26
2.7.2.1 Discrete and continuous speech recognition systems ……..…..27
2.7.2.2 Hidden Markov Model ……..……....27
2.8 Architecture for VoiceXML-based Systems ……....….28
2.9 Review of Voice-enabled systems ……..31
2.10 Review of Existing E-Education Frameworks and Systems ……..…..34
2.11 Client devices for voice-based systems ……....42
2.12 Measuring the usability of systems .. ……43
2.13 Summary ……44

CHAPTER THREE

3.0 THE INTELLIGENT VOICE-ENABLED E-EDUCATION FRAMEWORK 45

3.1 Introduction…….....45
3.2 Elicitation of Requirements ….……..45
3.3 The Framework ……...……...47
3.3.1 Application Interface……..48
3.3.2 Learning Objects……49
3.3.3 Learner's Profile…..……49
3.3.4 The adaptation component service …….……..….49
3.3.5 The recommendation component service ……..……...52
3.3.6 Ontology-based model of *iVeES* Framework……..…...55
3.4 Interaction Management.……...…….…61
3.4.1 The VUI Tree Framework …….……...….63
3.4.2 The Hidden Markov Model (HMM) Framework ……..….69
3.5 Summary ……....74

CHAPTER FOUR

4.0 *iVeES* DESIGN AND IMPLEMENTATION……..…75

4.1 Introduction…….....75

4.2 Architectural Design……....75

4.2.1 The Physical Architecture……....75

4.2.2 *iVeES* Application Architecture ……..77

4.2.3 The UML Deployment Architecture ……...79

4.3 A Description of CBR and Stemming Approach ……....80

4.4 Pseudocode for *iVeES* ……..…….....81

4.4.1 Algorithm Development…….……81

4.4.2. Voice User Interface (VUI) Design…….……..83

4.4.3 Sample (call flow) of the system ……..……84

4.5 Systems Implementation …….....85

4.5.1 Voxeo platform ……86

4. 5.2 Web user interfaces of *iVeES* ……..…….....86

4.5.3 Testing and Deployment…….....88

4.5.4 Accessing the application…….……....89

4.6 Benefits of *iVeES* ……..…91

4.7 Summary…….....92

CHAPTER FIVE

5.0 *iVeES* EVALUATION…….....93

5.1. Introduction…….....93

5.2 Research Design……..93

5.3 Lessons learnt …….…….94

5.4 Evaluation Results …….....95

5.5 Data Analysis ……..……99

5.6 Summary……102

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS…….…..103

6.1 Summary…….....103

6.2. Conclusion …….....104

6.3 Recommendations……...…105
6.4. Future work...……107

APPENDIX I: List of publications from the thesis…….…….108
APPENDIX II: List of Abbreviations and Symbols…….……..109
APPENDIX III: Sample Questionnaire……..……..……..112
APPENDIX IV: Sample VoiceXML Source Code…..…….. ……..117

REFERENCES……...…121

LIST OF FIGURES **PAGE**

Figure 1.1: Core of *iVeES* methodology……..……10
Figure 2.1: VoiceXML platform architecture……..28
Figure 2.2: Example of VoiceXML document…….31
Figure 2.3: Architecture for Voice-enabled Web-based absentee system…….....37
Figure 2.4: An m-Learning Framework ……...38
Figure 2.5: M-Learning Architecture with speech recognition enhancement …….39
Figure 2.6: Deployment Architecture of the Voice Interactive Classroom……...41
Figure 3.1: The system requirement for *iVeES* framework…….……..46
Figure 3.2: Intelligent voice-based e-Education system (*iVeES*) framework……..……..48
Figure 3.3: A model of score evaluation criterion…….……..…49
Figure 3.4: A UML sequence diagram for adaptation service……...51
Figure 3.5: Data flow diagram for adapting learning content in *iVeES* ……52
Figure 3.6: A Case structure for the system…….…….52
Figure 3.7: Recommendation Model of *iVeES* framework…….…...54
Figure 3.8: A UML sequence diagram for recommendation service……..…..55
Figure 3.9: Enhancing the weight of a term using Ontology……56
Figure 3.10: E-Education repository ontology as a class diagram…….…57
Figure 3.11: Main Classes of the Education.owl Ontology…….…….....58
Figure 3.12: Architecture of Education Ontology model……..…..59
Figure 3.13: A Screenshot of Education Ontology design using Protégé 3.4.1…….…....59
Figure 3.14: (a) A piece of RDF code and (b) The same information in OWL code for *iVeES*...60
Figure 3.15: Process flow diagram of *iVeES*……63
Figure 3.16: A VUI tree framework for the system……...64
Figure 3.17: The restructured VUI tree……..……67
Figure 3.18: The VUI tree ……..……68
Figure 3.19: Partial Call flow for the system……..68
Figure 3.20: Example of a three-state HMM……..70
Figure 3.21: The state transition diagram of *iVeES*……71
Figure 3.22: Format of state transition probabilities…….……..72
Figure 4.1: Intelligent voice-based e-Education architecture……76
Figure 4.2: An instance of intelligent voice-enabled e-Education Architecture……77

Figure 4.3: *iVeES* application architecture…….78
Figure 4.4: UML Deployment scheme for *iVeES* ……..…….80
Figure 4.5: A process model of tutorial questions for *iVeES*..……..……..81
Figure 4.6: Modified Porter Stemming (MPS) algorithm for *iVeES* ….…….82
Figure 4.7: Sample call flow of *iVeES*..……...…85
Figure 4.8: Voxeo IVR hosting platform…….…86
Figure 4.9: A screenshot of lecture note Web interface ……87
Figure 4.10: A screen shot of tutorial questions Web interface…….88
Figure 4.11: A screenshot of unresolved questions Web interface……88
Figure 4.12: Voxeo Prophecy SIP Softphone keypad……90
Figure 4.13: A model of mobile phone interaction with *iVeES*…….91
Figure 5.1: Mean rating for Q5 (Efficiency)…….....97
Figure 5.2: Frequency distribution for Q5 (Efficiency)…….....…97
Figure 5.3: Frequency data for Q5 (Efficiency) Histogram……..….98
Figure 5.4: Usability attributes analysis of *iVeES*..…..98
Figure 5.5: Effectiveness Analysis…..……..…99
Figure 5.6: Efficiency Analysis…….....100
Figure 5.7: User Satisfaction Analysis…….100
Figure 5.8: Learnability Analysis…….101
Figure 5.9: Memorability Analysis……..……101
Figure 5.10: Usability Attributes Analysis……...102

LIST OF TABLES **PAGE**

Table 3.1: Interpretation of Nodes in the VUI tree...……..……..…65
Table 3.2: Properties of VUI tree nodes…….……..…67
Table 3.3:State transition probabilities…….……...73
Table 4.1: VUI Design for getting learning content in *iVeES*……..…..83
Table 5.1: Descriptive Statistical Analysis of Questionnaire Data…….....94
Table 5.2: User survey results…….…….96

ABSTRACT

Voice-enabled e-Education system is the enabling technology that allows users to access Learning resources on a web using a telephone. Telephony applications in the area of education are developed mainly for the visually impaired to address the limitations of user interface of a mobile learner in accessing web learning resources. However, with the proliferation of learning resources on the web, finding suitable content (using telephone) has become a rigorous task for voice-based online learners to achieve better performance. The problem of Finding Content Suitability (FCS) with voice e-Learning applications is more complex when the sight impaired learner is involved. Existing voice-enabled applications in the domain of e-Education lack the attributes of adaptive and reusable learning objects to be able to address the FCS problem. Nevertheless, the adoption of artificial intelligence methodologies involving case-based reasoning (CBR) and domain ontology is required to provide recommender and adapted systems in voice-enabled learning towards solving the FCS problem. This study provides a framework for intelligent Voice-based e-Education Systems (*iVeES*) and an implementation of a system based on the framework with dual user interfaces – voice and web.

The framework was designed using schematic diagram, mathematical models and ontology; and implemented using PHP, VoiceXML and MySQL. A usability study was carried out in a visually impaired and a non visually impaired school using the International Standard Organization 9241-11 (1998) and Nielsen (2003) specification to determine the level of effectiveness, efficiency, user satisfaction, learnability and memorability. The result of the usability evaluation reveals that the prototype application developed for the school has "Good Usability" rating of 4.12 out of 5 scale. This shows that the application will not only complement existing mobile and web-based learning systems but will be of immense benefit to users, based on the system's capacity for taking autonomous decisions that are capable of adapting to the needs of both visually impaired and non-visually impaired learners.