

Summary

The last two decades have testified the massive and considerable development of information, computer and communication technologies. New techniques have emerged to convert the world in a small town, where its habitants in the east and the west can easily communicate with each others, as if they were living in the same neighborhood. Education has exploited these developments with the objectives to improve the way students, teachers and organizations exchange information and knowledge.

Traditional educational systems (just-put-it-on-the-web) make the course content available from a set of links that lead to different web pages, ignoring the student's background and knowledge acquired during his/her navigation within the course. This sometimes leads to students getting lost in the course hyperspace without achieving the learning objectives. Adaptive and intelligent web-based educational systems (AIWBES) are considered a good solution to this problem. Adaptive systems provide personalization of contents and links for different types of students and groups, while intelligent systems refers to the application of artificial intelligence (AI) techniques to provide broader and better support to the users of web based educational systems. AIWBESs are the result of the intersection of the Adaptive Hypermedia System (AHS) and Intelligent and Tutoring Systems (ITS). Some of their features are: *Navigation Adaptation*: It helps the student in hyperspace orientation and navigation by changing the appearance of visible links. This is done by link sorting, link hiding, direct guidance, annotation or mapping. Examples: ActiveMath, ELM-ART, KBS-Hyperbook, MLTutor and TANGOW. *Presentation Adaptation*: It adapts the content presented in each hypermedia page to student goals, knowledge and other information stored in the student model. Examples: ActiveMath, ELM-ART and TANGOW. *Curriculum Sequencing*: It helps the student to find the optimal path through the learning materials; ELM-ART, SQL-TUTOR and TANGOW are good examples of this method. *Intelligent Solution Analysis*: It tells the student his/her missing or incorrect piece of knowledge. Examples: ELM-ART, SQL-TUTOR, TANGOW and WITS. *Problem Solving Support*: It provides the student with intelligent help on each step of problem solving from giving a hint to executing the next step. Examples: ADIS and AlgeBrain.

Student models are considered the core of any AIWBES. They represent system's beliefs about the student's knowledge, interests and goals and they are constantly updated in accordance with the student

knowledge acquisition process. They can be classified according to a number of factors, ranging from how they are generated to their content, and also to their application. Overlays are considered the most common type of student models. They focus on modeling the student's domain knowledge as a subset of a teacher's domain knowledge. This means that the domain is decomposed into a set of elements and the overlay is simply a set of masteries over these elements.

Machine learning is the subfield of artificial intelligence that is concerned with the design and development of algorithms that allow computers to improve their performance over time based on data. These algorithms are used widely in education at a distance with objective to incorporate the concept of "adaptation" in current domain knowledge level of the student, content presentation, problem solving and in tutoring and communication with the student. The diversity of student's profile, background, preferences and skills about learning content are stored and updated constantly in student model. Neural networks (NN) and hidden Markov Model (HMM) are good examples of such algorithms and which are used in this research.

Artificial neural networks are considered as information processing systems that have certain performance characteristics in common with biological neural network. They consist of many interconnected neurons with familiar characteristics, such as inputs, synapses, weights, activation and outputs. Artificial neural network training methods can be identified as supervised and unsupervised learning; a target output pattern is associated with each training input pattern. On the other hand, during unsupervised learning the input pattern is only presented to the network. Bidirectional Associative Memory (BAM) is used and it is considered as a good example for supervised training, while Adaptive Resonance Theory (ART) and Fuzzy-ART2 are admirable models for unsupervised training.

Bidirectional associative memory (BAM) is a supervised neural network which is able to memorize binary, bipolar or continuous patterns with two-way retrieval capabilities. It is essentially used in the field of patterns recognition.

It consists of two layers of neurons arranged in X layer and Y layer, connected by bidirectional weighted connection paths. Its essential function is to store and retrieve pattern pairs. m and n denote number of neurons in X layer and Y layer respectively. Both layers serve as both input and output units depending on the direction of propagation.

Adaptive Resonance Theory (ART2) neural network is introduced as a theory of human cognitive information processing. It is an unsupervised neural network that based on competitive learning finds categories autonomously and learns new categories if needed. It is developed to overcome the problems of instability of feedforward systems, particularly the stability-plasticity dilemma.

The heart of ART2 network consists of two parts; the attentional subsystem and the orienting subsystem.

Where I is the input vector. p , q , u , v , w and x represent STM activities of F0 and F1 nodes. y is the STM activity of F2 node. Z_{ij} and Z_{ji} denote the bottom-up and top-down LTM adaptive filter respectively, and $f(x)$ is a nonlinear function. The attentional subsystem is composed of three fields; two feature representation fields F0 and F1 that include several processing levels and a category representation field F2 where competitive learning takes place. The combination of contrast enhancement, noise suppression, normalisation, and pattern matching is produced in F0 and F1. The two fields F1 and F2 are linked by bottom-up and top-down connections called adaptive filters or Long Term Memory (LTM). The orienting subsystem measures the degree of match between the bottom-up input pattern and top-down template pattern. It also helps guide the attentional subsystem in its search for a new category.

Fuzzy Adaptive Resonance Theory (Fuzzy-ART2) is a self-organizing neural network topology with dynamics based on Adaptive Resonance Theory (ART).

Neural networks are widely used in constructing AIWBES; Multi Layered Perceptron (MLP) is used within the KnowledgeClass system to find the best educational units which match the student's knowledge status, while Backpropagation neural network can predict future students' actions and reactions.

HMM is a probabilistic model used to align and analyze sequence datasets by generalization from a sequence profile. It is commonly used in speech recognition and its applications have been spreading steadily to other fields that include, e.g. communications, computational biology and e-learning systems.

Many educational systems use HMM. It is implemented In WELS (Web-Based English Learning System) to classify students in two groups (novice and advanced) with the objective to offer adaptive course for each group. IMMEX (Interactive Multi-Media Exercises)

utilizes HMM to model students' learning trajectories and to predict their future strategies.

HMM is extensively applied in predication applications. It is implemented in MANIC (Multimedia Asynchronously Networked Individualized Courseware) to prefetch lecture notes by predicting future browsing actions of specific users.

IWEBISE (Intelligent Web-Based Interactive System for Education)

IWEBISE is a new system introduced in this research for building Adaptive and Intelligent Web-Based Educational Systems (AIWBES).

These educational systems apply:

- Navigation Adaptation technique by sorting or hiding links in a page.
- Presentation Adaptation by applying page variants concept which links different types (Low, medium and high) of an educational content page according to students' knowledge status. It is also applied by ordering different parts (content, examples, exercises, post-test and conclusion) of a content page depending on students' learning styles.
- Curriculum sequencing by predicting next students' actions, this means the next future concepts will be visited by the student.

IWEBISE also uses a relational database for representing any course knowledge. An opened and overlay student model is utilized to store students' personal information and their knowledge level regarding course content.

The originality of this thesis is based on:

1. The discover and the use of a new neural network architecture called hierarchical HBAM for modeling domain knowledge of a course. This new network can be employed in many other fields such as: pattern recognition.
2. The use of a new hybrid algorithm using a neural network (Fuzzy-ART2) and a statistical method (HMM) in modeling student's knowledge.
3. The comparison of many machine learning algorithms such as: FBAM, ART2, Fuzzy-ART2 and a hybrid structure Fuzzy-ART2/HMM, which are used for categorizing students' thinking and reasoning into six levels; very weak, weak, fair, good, very good and excellent.

4. The use of HMM to predict the next concept, based on the history of concepts, visited by a certain student navigating within the course;
5. Discovering Higher Institute of Languages (University of Aleppo) students' learning styles in learning a language. This is done by using Felder and Silverman model.
6. The comparison of the new system IWEBISE with others adaptive and intelligent educational systems.
7. The ability of the new system IWEBISE to export and package courses according to SCORM standard with the objective to reuse them within others educational platforms such as: MOODLE.
8. The construction and implementation of a new intelligent and adaptive web-based educational system for teaching English grammar.

This thesis is organized into thirteen chapters as follows:

Chapter I: This chapter explains the methodology employed in this research to obtain an intelligent and adaptive system with high performance in creating on-line courses with content adapted and tailored to students' learning style and knowledge status. It also details the main and secondary objectives, the feasibility study, research questions, requirements, limitations and importance.

The other twelve chapters are distributed in three parts;

Part I (Theoretical Framework): This part exhibits the research theoretical framework and it consists of four chapters:

Chapter II (Artificial Intelligence, Learning, Teaching and Instruction): This chapter focuses on the definition of artificial intelligence, teaching, learning, instruction, learning/instruction theories and how they are used together to produce intelligent educational systems.

Learning theories focuses on how knowledge is organized in learner mind and it could be sequential, spiral or pyramid. Instructional theories explain different strategies used by teachers to display course content. There are three main categories or philosophical frameworks under which learning and instructional theories fall: behaviorism, cognitivism, and constructivism. Constructivism is used in our new system IWEBISE for building adaptive and intelligent web-based educational courses. Ausubel's concepts Maps are utilized for tailoring course content and Piaget's learning cycle is also employed

with the objective to provide students an exploratory environment which supports intelligent self learning.

This chapter also focuses on students' learning style models and presents some kind of them, but it concentrates on Felder and Silverman model. As well E-learning standards are explained, especially SCORM and its components. At the end of this chapter different levels and styles of interactivity are detailed and how they could be utilized within educational systems.

Chapter III (Hypermedia and Educational Systems): It begins with the concept of hypermedia systems and their techniques (Navigation and Presentation Adaptation), then it reviews the development of educational systems covering Computer Assisted Instruction (CAI), Intelligent Computer Assisted-Instruction (ICAI), Intelligent Tutoring system (ITS), Adaptive and Intelligent Web-Based Educational System (AIWBES) and Learning Management system (LMS). ITSs use Curriculum Sequencing, Problem Solving Support and Intelligent Solution Analysis techniques, while AIWBESs use Adaptive information filtering, Intelligent Collaborative Learning and Intelligent Class Monitoring techniques. This chapter also details the three generation of Adaptive Hypermedia Systems from the beginning of nineties till our days. At the end, some educational systems are presented as examples of all the above mentioned systems.

Chapter IV (Student Model and Tutor Model): It provides the theoretical concepts related to the heart of any intelligent and adaptive educational system which is presented by "Student Model" and "Tutor Model", as well it presents the kind of information that could be employed in the student model. Finally, the chapter reviews some kind of student and tutor models with some examples for each one. Student model could be: Stereotype Model, overlay Model, perturbation Model, Tracing-Model or constraint based modeling, while Tutor model could be: Socratic, Coach, Learning by doing or Learning while doing.

Chapter V (Machine Learning): It gives a high review of some machine learning algorithms such as: Neural Networks (BAM, ART2 and Fuzzy-ART2) and Hidden Markov Model. These algorithms are used within student and tutor models to represent students' knowledge and tutor decisions in giving their students appropriate assistance during the learning process in a timely manner respectively.

Part II (IWEBISE): IWEBISE consists of five modules: Domain Model, Student Model, Tutor Model, Adaptation engine and Users' interfaces, where each module is detailed in a separate chapter:

Chapter VI (Domain Model): The course content is organized into a concept network to represent learning objectives. A learning objective (LO) concerns several concepts which are classified in: main concepts (MC), prerequisite concepts (PC) and sub-Concepts (SC). Each internal node in the network represents a concept, and external nodes in the lowest level symbolize several types of educational units (EU), which are in the form of interactive flash multimedia files, images, videos, texts, exercises, examples and tests.

Three methods are used to model course content with the objective to choose later the best one of them:

In the first method the domain knowledge is conceived and modeled using a hierarchical BAM neural network. The first BAM-1 is to associate learning objectives with concepts and while the second BAM-2 is utilized to assign educational units to each concept. The output layer of BAM-1 is the same input layer of BAM-2 which can be seen as an intermediate layer of the whole architecture. Number of nodes of the input, middle and output layers represent number of learning objectives, concepts and educational units.

In the second method a relational database is used to represent domain knowledge. It consist of eleven tables (Main Category, Subcategories, subjects, Learning objectives, Prerequisite-learning objectives, concepts, Prerequisite-concepts, attach a sub-concepts with concepts, concept content and test items).

A Document Type Definition (DTD) file is constructed in the third method to determine a set of rules to define and describe the organization of knowledge within an XML file.

At the end of the chapter course packaging algorithm using SCORM standard is detailed with the objective to reuse them within other LMS systems.

Chapter VII (Student Model): This chapter details how students' learning style is modeled according to Felder and Silverman model which depends on many parameters such as: Number of examples, number of exercises, examples before or after content and exercises before or after content.

Students knowledge is expressed in the system by using the overlay model which considers it a part of the knowledge domain. The IWEBISE also uses an opened student model, which allows students

to change by themselves their knowledge status related to each concept in domain knowledge; this permits them to study with wide steps without feeling blocked during their learning process. The student model is composed of two parts:

- Static part: It keeps student's personal information.
- Dynamic part: It maintains the record of the students' understanding as the course progresses on the basis of their responses. The personalization of navigation through the course content depends on several parameters taken from the interaction of student with the system. These parameters are: number of correct answers (NCA), number of incorrect answers (NICA), time spent to solve a question (TSSQ), time spent to reading or interacting with a specific concept (TSR) and number of attempts to answer a question (NAAQ). Once a student passes a pre-test session, the dynamic part is initiated using these parameters. Using these parameters six methods are employed to symbolize student's knowledge status in six levels (Excellent, very good, good, rather good, weak and very weak) with the objective to determine the best one to be used later within IWEBISE. These methods are: FBAM, ART2, Fuzzy-ART2, HMM and NN/HMM.

At the end of this chapter, all previous algorithms performance is evaluated by employing F-measure metric to determine the best one to be used later in our new system.

Chapter VIII (Tutor Module): This chapter explains in details how to model different teachers' strategies in presenting course content to students. This is done by having them in a table consisted of nine fields which allow to store colors utilized to represent students' knowledge status in the course map and the possibility of showing or hiding a learning concept. Chapter VIII also focuses on a prediction algorithm to foresee the next concepts might be visited by students.

The prediction process is achieved by following three phases:

- Initialization phase: For each student a HMM (λ) is built based on his/her previous concept access sequences.
- Adjustment phase: Given a new observed sequence and a HMM (λ), the Baum-Welch algorithm is used to adjust the initialized HMM and to maximize the new observed sequence.
- Prediction phase: The Forward Algorithm is applied to determine the probability distribution of each concept (state) in the course. The highest value represents the next concept will be visited by the student.

Finally, the students' actions prediction accuracy is measured with the recall (sensitivity) and precision measures. The sensitivity is defined as the number of correctly predicted concepts (true positives) divided by the number of annotated concepts (actual positives). The precision is the percentage of positive predictions that are correct.

Chapter IX (Adaptation Engine): This chapter details the two adaptation algorithms used in tailoring the two following points to student:

- Concept content concerning students' learning style depending on Felder and Silverman model.
- Learning concept map according to students' knowledge status.

In addition chapter IX shows:

- How different adaptation technologies are used in IWEBISE such as: Adaptive Presentation, Adaptive Navigation and curriculum sequencing.
- How constructive theory is applied and used by the intelligent tutor.

Chapter X (Users Interfaces): This chapter exhibits some windows used to facilitate the interaction among different users of IWEBISE.

These windows are classified in four levels:

- Administrator Interface: It permits administrators to create course category, subcategory, users management and subscription process.
- Designer Interface: It permits course designers to manage learning objectives, learning concepts, subconcepts, concept content and tests questions. It also permits them to package the whole course under SCORM standard.
- Tutor Interface: Teachers can manage their teaching strategies rules and trace students and give them the appropriate advises when they deviate from the final goal of the course.
- Student Interface: Students can complete their learning process by using pretest, post-test, "Index Learning Style" questionnaire, glossary, chat and forum windows.

Part III (Implementation Phase): The critical phase of any life system cycle is the successful execution of the different parts of the system for reaching its objectives and requirements. This is done by putting all those parts in practice with the intention to detect any inconsistencies could be existed between them and then to optimize them. Part III consists of three chapters as follows:

Chapter XI (Programming): This chapter details scripts tree of the new system, additionally all the functions employed to model students' knowledge and to predict their future actions within the course. These algorithms are : BAM, ART2, Fuzzy-ART2 and HMM.

Chapter XII (IWEBISE Testing): Testing step is performed on the entire tool units. “Teaching English Grammar as Foreign Language” course is taken as an application example for carrying out this step. This course is uploaded first by one designer and then by many designers just to verify the ability of IWEBISE to apply collaborative design. It is also monitored many students during their learning process to test the two adaptation mechanisms related to students 'knowledge status and their learning style. Finally, course packaging under SCORM standard unit is also tested.

Chapter XIII (IWEBISE Evaluation): This chapter concentrates on the evaluation phase of IWEBISE which consists of many steps:

- Defining Evaluation Objectives: Evaluation phase aims at measuring system impact on its users and how easy of use and understand.
- Planning: This step consists of many points:
 - Selecting Evaluators: Teachers and students from University of Aleppo are selected to evaluate IWEBISE.
 - Tasks Definition: Tasks for teachers and students are defined as follows:
 - Teachers' tasks: (Create new course, Add learning objectives and concepts, test items, upload files and course packaging).
 - Students' tasks: (Course access, presenting pre-test, navigating 2 to 10 concepts and presenting post-tests).
 - Questionnaire Design: Teacher's and student's questionnaires consist of 37 and 30 closed questions respectively, according to Likert scale which is widely employed to measure users' satisfaction. Only four scales (strong disagree, disagree, agree and strong agree) are used to avoid intermediate decisions.
- Evaluation Conducting: The evaluation phase is carried out by giving a workshop separately for 10 teachers and another one of 3 hours for 20 students. At the end of each workshop, questionnaires are distributed to collect their opinions.

- Evaluation results analysis: Results are analyzed to highlight how IWEBISE is easy of use and understand.

Final conclusions summarize the general results of our research which have facilitated the construction of a new *intelligent web-based interactive system for education*. This system is effective, consistent, easy of use and understand in managing both learning and teaching processes.

This research ends with a table of future recommendations, references and many annexes. Annex I refers to "Index Learning Style" questionnaire, while Annex II illustrates some examples of students' responses to ILS, Annex III depicts the course map used as an application example for testing our new system, Annex IV presents results collected by evaluation questionnaires from course designers and students and finally Annex V presents different acceptance letters or e-mails of papers submitted to many international conferences and journals.

Conclusions

IWEBISE is a novel approach described in this thesis. It is used to build adaptive and intelligent web-based educational system utilizing Fuzzy-ART2 algorithm, with the objective to determine and draw students' paths through their navigation in the hyperspace of the course, avoiding them to become overwhelmed with too much text, links and images. Additionally it offers a potentially attractive way to classify their knowledge status in six different levels. Courses built using the new system are also adapted to student learning style using Felder and Silverman model.

The work in this thesis carries out the following points:

Domain Knowledge

- The course knowledge is organized into a concept map as following:
 - Principal composite concept which represent the same course.
 - Learning objectives (LO) concern several concepts which are classified in: main concepts (MC), prerequisite concepts (PC) and sub-Concepts (SC). Each internal node in the network represents a concept, and external nodes in the lowest level symbolize several types of educational units

(EU), which are in the form of interactive flash multimedia files, images, videos, texts, exercises, examples and tests.

- The course knowledge is modeled using three different methods:
 - Bidirectional Associative Memory neural network:
 - HBAM is considered a new method for knowledge representation.
 - HBAM is a new neural network architecture which could be used in many other fields such as: pattern recognition.
 - Recall time of HBAM is very huge and it is considered a time consuming for determining any kind of concept to be displayed, this sometimes leads the student to be very slow during his/her learning process.
 - HBAM does not offer a standard and a fixed architecture to be considered ideal to represent any course knowledge within any intelligent educational systems, due to the necessity to be retrained every time the teacher wants to add any concept to the domain model.
 - HBAM is not able to separate the course content from its architecture, due to the necessity to be retrained every time the teacher wants to link the same learning unit with two different concepts.
 - Relational database using MySql
 - Eleven tables are built to model different concepts encountered within the domain knowledge :
 - Main categories table to represent main classification of the course.
 - Subcategories table to represent sub-classification of the course.
 - Subject table to store course characteristics.
 - Learning objectives table to represent learning objectives features.
 - Prerequisites of Learning Objectives table to determine the prerequisites of each learning objective.
 - Concepts table to store main concepts.
 - Prerequisites of concepts table to determine the prerequisites of each learning main concept.
 - Sub-Concepts table to store the course glossary.

- A table to link sub-concepts to a concept.
- Concept contents table to store the content of any concept in many levels.
- Test items to store questions used in pre-tests and post-tests.
 - Relational databases are considered very fast for data retrieval and manipulation due to their architecture which optimize their performance, but at the expense of the flexibility.
 - Relational databases have an excellent security in giving permissions and privileges to access the data.
- XML
 - A Document Type Definition (DTD) file is constructed to determine a set of rules to define and describe the organization of knowledge within an XML file with the objective to represent the domain knowledge semantically. The obtained “IWEBISE.DTD” file has a general structure and it could be within other courses in different domains.
 - XML could not be considered as an alternative of relational databases, but its importance comes from its ability way to convert and describe the course knowledge.
 - XML separates the course content from its format.
 - Using XML makes course content reusable and interoperable within other educational systems.
- Relational database is selected to be used within our new system IWEBISE due to the following reasons:
 - Some course designers prefer to have their course contents confidential and protected.
 - XML could not treat huge course contents and all kind of data such as images and video.

Student Model

- The ability of the students to change their knowledge status allows them to finish the course with wide steps and without feeling blocked and limited to the system suggestions and curriculum planning, this was done thanks to the use of open student model technique.
- The static part of the student model is constructed employing four

tables:

- Users' table stores information related to users' personal and system access data.
- Students' group table relates students with each others to grant the teacher the ability to manage them during chat sessions, e-mails messages, assignments, etc more easily.
- Inscription table relates students' and teachers' records with courses' records.
- Index learning style table stores students' responses to the ILS questionnaire to determine their learning styles.
- The dynamic part of the student model is built employing three tables:
 - Students' interactions table traces students' movements during their navigation within the course content.
 - Students' responses table guards all students' responses to pre-tests and post-tests.
 - Students' knowledge map table stores students' knowledge status related to each node encountered within the course map.
- Students' learning styles at Higher Institute of Languages (University of Aleppo) are defined using Felder and Silverman model, this is done by distributing questionnaires to one thousands students of English, French, German courses. Results showed that:
 - Students prefer to study a foreign language utilizing the following parameters:
 - Reading a huge number of examples.
 - Doing a lot of exercises.
 - Preferring to read examples before content
 - Preferring to have exercises after content.
 - Preferring to have post-tests after content.
 - Displaying map course before, after or between learning objectives.
 - Displaying conclusion before or after concept content or composite concept.
 - Content type is visual.

These parameters are used when a student skips the ILS questionnaire, this means they are considered and defined as default standards within IWEBISE system to generate intelligent and adaptive courses not only in learning languages domain, but also in any other domains.

- 62.5% of students at Higher Institute of languages are active, 87.8% are sensitive, 74.3% are visual and 66% are sequential.
- Students' vectors are categorized into six levels to represent their knowledge status. This is done by applying six different methods:
 - Traditional method:
 - Two rates are utilized which are dependent on the time spent (T) on a concept and the answered questions (Q).
 - The extracted rules used in this method might be different from teacher to teacher, this leads sometimes to students' misevaluation, and then the course plan could not be suitable for their needs and levels.
 - FBAM method:
 - FBAM is set to have 5 nodes in the input layer and 6 nodes in the output layer.
 - FBAM could learn and categorize all students' vectors successfully with average 30 minutes.
 - FBAM could recall and categorize all trained students' vectors and new ones too successfully with 100% percentage.
 - Defining training pairs' process for FBAM is very complicated, time consuming and inaccurate too, this is due to the different thresholds might be employed by teachers and vary from one to another.
 - ART2 method:
 - ART2 is configured to consist of 5 nodes in F0 and F1 for each processing level and 6 nodes in F2 representing different knowledge status.
 - ART2 could recall 1500 trained students' vectors and 500 new ones with 85.80% successfully and stably.
 - ART2 could be trained with a time average 20.80 seconds for each vector and it could recall them with a time average 19 seconds.
 - ART2 could not learn if the vigilance parameter is high.
 - ART2 could not sometimes learn all students' vectors due to the bad choice of network parameters which play an important role in pushing ahead the training and recall phases.

- Numbers of input vectors also play an important role in recall phase.
- Fuzzy-ART2 method:
 - Fuzzy-ART2 is configured to consist of 10 (5x2 for complement coding) nodes in F0 and F1 for each processing level and 6 or 12 (6x2) nodes in F2 representing different knowledge status.
 - Fuzzy-ART2 network could learn stably and generalize well with only 30 vectors which are selected randomly for training phase, while the others 1970 are employed to test its performance.
 - ART2 could recall 1934 new students' vectors with 98.17% successfully and stably.
 - Fuzzy-ART2 could train and recall trained students' vectors with a time average 19.2 and 18.6 seconds for each vector respectively. Fuzzy-ART2 takes less time than ART2 to train or recall a vector; this is due to the use of fast learning.
- HMM method:
 - The number of hidden states of HMMs affects their performance, e.g. No. 3 is considered the optimal to get the highest recall performance percentage 66.40%.
 - The length of the input vector (observation sequence) which is 6, is also affects recall performance.
 - HMM could classify students' vectors with a time average 19.1 seconds for each vector.
 - HMM could recall trained students' vectors and new ones with a time average 17.6 seconds for each vector.
- Fuzzy-ART2/HMM method:
 - The optimal number of states for classify students' vectors is 6 because recall success is 92.66%.
 - The new hybrid algorithm took advantage of the two algorithms in improving recall performance from 66.40% to 92.66% in comparison with HMM.
 - The new hybrid algorithm could also shorten the categorization time to 17.1 seconds.
- F-measure metric is employed to measure all the above mentioned algorithms performance. Results show that Fuzzy-ART2 gives best categorization quality (0.281 as it is depicted in the following table), which is considered a very important factor to assure that an

appropriate course map is displayed to the student according to his/her knowledge status. This pushes him/her to finish the course completely without feeling boring and lost in it.

Algorithm	Time average training (Seconds)	Time average recall (Seconds)	Percentage of Recognition	F-measure
ART2	20.8	19	%85.80	0.250
Fuzzy-ART2	19.2	18.6	%98.17	0.281
HMM	19.1	17.6	%66.40	0.195
Fuzzy-ART2-HMM	30.6	17.1	%92.66	0.259

- Student model plays three vital roles during adaptation process within IWEBISE system:
 - As a planner of page content using Felder and Silverman model.
 - As a planner of course map using the hybrid algorithm Fuzzy-ART2/HMM.
 - As a student learning process observer using tables stored in the dynamic part of student model.

Tutor Model

- Teachers' strategies are modeled employing a table called Pedagogical rules. Standards rules were also defined and used if the teachers do not insert any new rules related to their courses.
- HMM algorithm is also employed to predict future students' actions.
- Sensitivity (Recall) and Precision measures are employed to evaluate the performance of prediction algorithm and the following results were obtained :
 - HMM generates a higher precision with higher sizes of training sets which vary from 20% to 99%.
 - The prediction precision reaches to 91% using 99% of training set.
 - When precision is high the sensitivity is high too.
- Tutor coach method is applied in tutor model through displaying a suggested next concepts list to students.

Adaptation Engine

- Adaptation engine is considered the most important module of the new system IWEBISE because it joins all others modules (Domain Knowledge, Student Model, Tutor Model and User Interfaces) with each others and it is responsible of producing :
 - Course pages adapted to student's learning styles and knowledge status.
 - Links to associate course pages together (Course map).
- Adaptation engine consists of two mechanisms:
 - Adaptation according to student's learning styles
 - Adaptation according to student's knowledge status.
- Adaptation process is summarized in four steps to present instruction strategy employed by the intelligent tutor. These steps represent Piaget's learning Cycle: Discovering, explanation, extending and evaluation.

User Interfaces

- User interfaces are categorized into four levels regarding users' profile: Administrators, Designers, Teachers and Students.
- Course designer interface permits to upload, manage, share and export course content under SCORM standards to be used later within others platforms such as Moodle.
- Tutor interface allows each teacher to add pedagogical rules and to follow the student's steps and progress during his/her learning process.
- Administrators interface allows them to manage system's users, course' categories, subscribe or unsubscribe students to a course, assign tutors to a course and manage language interface.
- Student interface permits the student interacts with the different learning objectives and concepts of the course. It consists of a window partitioned into 6 areas:
 - Index area: Where a map of course content is displayed to give the student the freedom of surfing among different learning objectives. It also contains a legend of colors to refer students' knowledge status related to each concept.
 - Navigation area: Where concept content is illustrated. It consists of : introduction, examples, content and conclusion ordered and displayed according to student's learning styles.
 - Post-Test area is exhibited dynamically at the top or at the bottom of the content page depending on each student's

learning style. It has a link which displays a window containing post-test questions.

- Exercises area: It has a link to depict a window with exercises related to the current concept. It is also adapted to each student's learning style.
- Prerequisite area shows a link related to all prerequisite concepts related the current concept.
- Glossary area: where sub-concepts presented to support and accelerate student's learning process. It is displayed at the right top of the content page.

Programming

- IWEBISE is constructed using PHP, JavaScript, CSS and MySql.
- IWEBISE scripts tree consist of 17 folders which contains more than 100 files to perform system administrators, designers, tutors and students tasks, with the objective to build adaptive and intelligent web-based courses.

IWEBISE Test

- IWEBISE system is tested by designers and experiments showed that it applies collaborative design which permits to build a learning objects library.
- Learning objects library allows designers to interchange, share and export their learning objects. This feature saves designer's time in building their future courses.
- IWEBISE is also tested by students and experiments exhibited the following results:
 - Presentation adaptation is applied as follows:
 - Page content is adapted and organized according to students' responses to ILS questionnaire which determine their learning styles.
 - Six levels of concept content could be displayed to students (text-low), (text-medium), (text-high), (visual-low), (visual -medium) or (visual -high).
 - Navigation adaptation is applied as follows:
 - Course map uses colored boxes according to pedagogical rules used by the teacher to express students' knowledge status.
 - A help link is used to allow students know prerequisite concepts related to the actual one.

- Some learning objectives or concepts are hidden if students do not achieve an appropriate level of their prerequisite concepts; this is also depending to teacher's pedagogical rules.
 - Course map is displayed adaptively depending on students' knowledge status.
 - Curriculum sequencing technique is also applied through displaying a suggestions list to students which recommend them the best next concepts should be followed by them.
- Course packaging using SCORM standard is tested and a compressed file is obtained which consists of:
 - A folder stores course pages.
 - A folder contains objects learning.
 - immanifest.xml file.
- The compressed file is imported by MOODLE system successfully, this means that IWEBISE is a powerful tool to create reusable and interoperable courses with other LMS systems using SCORM standard.
- Packaging courses using the new system IWEBISE is easy and very fast.

IWEBISE Evaluation

- IWEBISE is evaluated concerning course designer and students point of views, with the purpose to optimize its performance during teaching and learning processes.
- Twelve criteria are used to evaluate the new system IWEBISE : Consistency, Self-Evidence, Predictability, Richness, Completeness, Motivation, Hypertext Structure, Autonomy, Easy of use, Aesthetic, Collaborative, and Interactive. Evaluation phase results are:
 - Designers and students' interfaces are steady and reliable, this means that IWEBISE provides consistency concerning its layout and many other aspects like edit, create and navigate.
 - System tools are unambiguous because users could understand easily the objectives of objects (icons, texts, buttons, colors) displayed to them, this feature pushes the design and learning processes ahead rapidly.
 - Most of the time users get the expected output.
 - The new system is rich in terms of tools and helps to

facilitate the design and learning process, but some helps' features should be optimized to be at users' reach at any time.

- IWEBISE provides users with sufficient and plenty tools to cover all their objectives during design and learning process, but other asynchronized tools should be add such as: video – conference.
- Links existed among designers or students' tools need more refinement and improvement to obtain a better and organized structure.
- IWEBISE comprises abundance tools and controls which allow users to feel independent and autonomous during their interactions with the system.
- IWEBISE tools are clear and easy of use because users do not need any training course and they can explore the work and learning environments by themselves.
- IWEBISE tools are designed harmoniously with each others and this characteristic enforces the system to be self-evident and make users to focus on their primary goals.
- IWEBISE comprises collaborative tools which allow:
 - Designers to share their learning objects with each others and create courses in groups.
 - Students to apply collaborative learning using forum, chat, etc.
- Users' interfaces are interactive and respond to their necessities rapidly at suitable time and place.
- IWEBISE applies interactivity as follows:
 - Student – Teacher: Using e-mail, forum, chat, announcements and homework.
 - Student – Student: Employing e-mail, forum and chat.
 - Teacher – Content: Using course management tools.
 - Content – Content: Utilizing sharing learning objects option and using course packaging under SCORM standard.
- IWEBISE uses different levels of interactivity as follows:
 - Second level (Hierarchical Interactivity): Students can navigate the course content by using a hierarchical map, which consists of many levels to represent course structure.
 - Third level (Update Interactivity): The new system traces students' steps by updating their model in order to present adaptive content.

Learning Style									
	no	no	honey	no	no	no	no	no	Felder and Silverman
Standards									
							IMS SCORM IEEE	IMS SCORM IEEE	SCORM
Student Model									
Store student model	yes	yes	yes	yes	yes	yes	yes	no	yes
Open	no	no	no	no	yes	no	no	no	yes
Content Tools									
Content management	yes	yes	yes	no	no	yes	yes	yes	yes
Import content	no	yes	yes	yes	yes	no	yes	yes	no

According to the above results, it could conclude that:

- A new **Intelligent WEB-Based Interactive System for Education (IWEBISE)** is developed, tested and evaluated successfully and effectively.

Recommendations

- Add new tools to the new system IWEBISE which help to improve the both teaching and learning processes such as: Tests (quizzes) management tool, Templates management tool, calendar, news, etc.
- Add new tools to help designers to build courses for handicap people such as: course reader for blind people, special templates for visually impaired people, and using access keys for movement impaired people too.
- Add an intelligent search engine to help users achieve their goals rapidly; this could be done by clustering algorithm such as Fuzzy-ART2.
- Take in consideration more students' parameters with the objective to get an optimal student model. These parameters could be: Bandwidth, operating system, Internet Navigator, screen resolution, microprocessor, keyboard, text size and type of device (mobile or normal computer).
- Apply adaptations techniques in selection tests items.
- Optimize HMM algorithm using fuzzy logic in predicting future students' actions and comparing results with the actual ones.
- Add group model to apply collaborative learning.
- Add intelligent collaborative learning technique by including Group model.
- Compare the obtained results with Bayesian algorithm to detect the best.
- Take in consideration students' errors to give them suitable and intelligent feedback while they doing or resolving problems.
- Add an import tool to make the new system able to upload courses constructed using other LMS systems.
- Implement the new system IWEBISE in real educational institutions and virtual universities with the purpose to improve it and get a better performance.

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