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ADAPTIVE VISUALIZATION FRAMEWORK FOR USER-INTERACTION WEB-BASED E-LEARNING SYSTEMS

Dr. Nedhal A. M. Al-Saiyd

***Abstract*—Human-computer interaction requires a software user interface to facilitate the communication to the user. The user interface plays a significant role in the user acceptance of software systems design. In Web-based e-learning systems, the need for adaptive personalization is increased because it is of particular importance in Web-based data accessing, providing relevant information and e-lectures effectively, and improving user performance and satisfaction. In this paper, we propose a framework for adaptive visualization for the interface of Web-based e-learning system. The important characteristics; that consist of user's preferences, background knowledge levels, needs, cognitive abilities, interface layout diversity, and interface structure are identified. These characteristics have a significant impact on the model to make the interface flexible, consistent, less complex, and more practical. The design is based on using weighting probabilistic scheme and artificial intelligence reasoning techniques to provide the users with relatively customized, reliable, and dynamic data to be used easily, while earlier were providing slow and static data. Short-term modeling and long-term modeling of learning algorithms, which are based on similarity-based visualization, are conceptually presented. They support e-learning users to assess, retrieve the right information, and facilitate the e-lectures classification.**

Keywords—Adaptive Visualization, Adaptive User Interface, Adaptive Intelligent Learning, Personalization, Usability, Adaptive Knowledge-Based Visualization, Similarity-Based Visualization

I. Introduction

Human-computer interaction requires a software user interface to facilitate the communication to the user. The quality of the interaction is based on how easily can be understood and used, how efficiently the interface design is, how effectively can understood the needs of users with different and wide range of abilities, knowledge, and skills, users' memorization requirements [1], how the interface can considered consistent and attractive, and how efficiently it can be managed and adapted. Users may have enough knowledge and skills to perform the tasks easily, while other tasks may require system assistance to help them to complete the tasks Another consideration is to have simple and attractive layout design [2], [3], [4].

Associate Prof. Dr. Nedhal A. Al-Saiyd
Computer Science Dept. Faculty of Information Technology, Applied Science University,
Amman-Jordan,

Day after day Websites and the information systems are getting much complex in terms of services, interaction model, size and speed. Such systems were providing slow and static data. The user’s preferences, interests, abilities, interaction styles (e.g. how users interact with others), and knowledge level are quite different from one user to another and it cannot be predicted in advance. The old interaction model is based on "one-size-fits-all" approach; i.e. a unified user interface, that is designed for the average users. A unified user-interface cannot cover all the abilities of interface users [5].

Most of the traditional user-interface approaches face these limitations [6]:

- Does not understand user divergences; i.e. – different user interests or different contexts,
- Does not provide customized results for particular user interest under different context,
- Some interfaces are impractical for people with impairments,
- They do not adapt to users whose abilities are changed frequently,
- Some software systems are neglected, even by users who need them, because of interface factors like complexity, and the need for ongoing maintenance, and
- Often most of the user interfaces are designed disregarding the fact that design preferences differ between users' background knowledge.

Therefore, a new different approach is needed to overcome the traditional problems and to adapt to user's abilities and needs. Adaptive Web-based learning system is an intelligent system that is acquiring knowledge from user access patterns, and delivers the right content to users at the right time while taking into account users' preferences. It automates the selection of visualization, and different user's perspective of the same data visualization. Intelligent Web-based learning environment that uses artificial intelligence reasoning techniques also gives a special attention to the interaction with the user. The adaptation to different user's preferences, interaction styles, and knowledge levels can improve usability, user performance and satisfaction [7] [8].

One of the most important key components in the success of a Website is determined by Website usability. Usability is closely related to software design [9]. It not only allows the Web users to transfer easily and conveniently, but also helps them to find conceptually relevant information. Usability is related to: user's ability to achieve specific goals in the environment effectively, the using resources (time, money, and mental effort) when performing a system-supported task efficiently, and the user's Satisfaction level and acceptance of the system overall. Shahizan and Li applied IGV approach that Identify 52 key criteria; Group them into seven categories- screen appearance or layout, content, accessibility, navigation, media use, interactivity and consistency; and Verify the identification and grouping. Screen appearance refers to the user interface of the website that may affect Web usability. It can be divided into 4 categories - space allocation, choice of color, readability, and scannability [10], [2].

The goal of this research has twofold: (1) to present an intelligent interface agent to develop better adaptive visualization methodology and explore its characteristics; and (2) to implement the adaptive visualization using concept-based user modeling. To achieve this goal, we need to explore the user by analyzing the existing user interface of Web-based e-learning system to gather the factors that influence the derived user model. Our objective is to identify important characteristics that can make the interface flexible, consistent, less complex, and more practical that is used by many different users as possible. It can considerably improve the accuracy, quality and efficiency for typical users of daily interactions.

The rest of paper is organized as follows: section 2 describes the main domain areas of user model and their relationships. In section 3 the proposed Adaptive Visualization Framework is proposed. The Adaptive Knowledge-based Visualization is discussed in section 4. Section 5 presents User Profile using Learning Algorithm and describes the short-term and long-tem modeling. And finally, the conclusions are summarized in section 6.

II. Domain-Areas of User Model

We can consider that user interface model has two domain areas: (1) Personalization and (2) user interface Visualization (UIV). The adaptive visualization is considered as the relationships that combine between these two areas. Fig. 1 depicts the three different aspects user model.

The proposed methodology will take into consideration; users' background knowledge, preferences, needs, interface layout diversity, and interface structure to obtain the logical relations among the interface objects, and categorization of pedagogical materials into (simple, Moderate, Hard) levels, the education level, content structure.

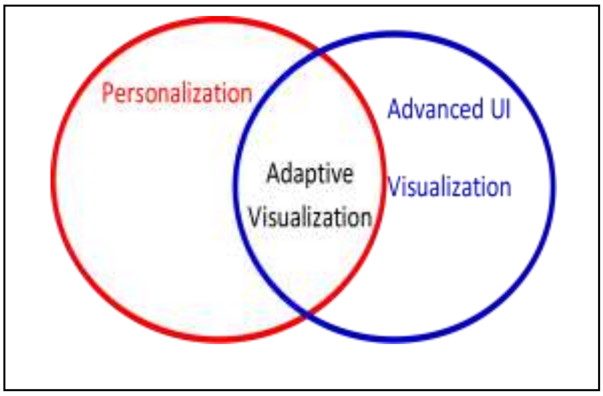

Figure 1. The adaptive visualization using concept-based user modeling

A. User Interface Visualization

Information visualization gains widespread importance in the research area of human-computer communication domain. Visualizations can be used to collect the knowledge about a complex domain and performing low-level tasks and involve a reasoning process. Visualization cannot be well-understood without understanding how the user of visualization thinks. There is no single type of user's visualization [11]. Traditionally, visualization software has focused primarily on how data can be transformed to visual forms and how people understand them. It was designed for a single ideal user; “one-size fits-all”, since it was impractical to develop interface visualization for each individual user. Recently, users depend on visualizations to help them in solving complex and analytical tasks, where each user has different aspect. Users have significantly different backgrounds, personalities, experiences, and cognitive abilities, and all of these will influence users's approach to understand the problem domain, to solve any task and retrieve information.

Data visualization techniques can be classified as static visualization and dynamic visualization of data. Static data visualization is formed by certain data sets in static forms, as static forms that also represent static value. On the other side, the data are changing with certain time frames in dynamic visualization technique. Visualization can have two or three-dimensions. Two-dimensional visualizations can be represented as graph or tree-like representations, which contain many nodes and arcs [12].

B. Personalization

Personalization of user interfaces has become an essential issue in usability of many software products reduce visual complexity and improve interaction efficiency. Personalized user interface is tailored to an individual user’s needs and provide him with many necessary features to support a wide range of tasks and make novice users faster, more accurate and more satisfied. With adaptive split menus that uses frequency-based strategy, for example, the menu items that are most commonly used and needed by the user are automatically moved to the top of the menu to make them accessible more easily, or by hiding those items that are predicted to be the least useful. Layered interfaces allow the user to switch between several interfaces and choose the one that better fits a user's current task at a given time [13], [14].

C. Adaptive Visualization

From the user's side, the adaptive systems require little or no knowledge and effort, but developing a consistent model of a system can be problematic because of development difficulties. In adaptable interfaces, the users have the responsibilities of learning and performing the adaptation tasks.]. It is important to identify the characteristics that influence an individual user’s effectiveness, efficiency, and satisfaction with a particular information visualization type [15]. This will help to successfully perform the adaptation to the specific needs, characteristics, and context of each user. Adapting the visual appearance of items, locality (i.e. at the location where the user would look by default), and color highlighting has the ability to reduce the visual search component of item selection [14].

III. Adaptive Visualization Framework

The challenge is to find adaptive visualization framework that performs fine-tuning to the user interaction of Web-based e-learning system. A variety of aspects should be considered:

- User Adaptation or Personalization: The personalized systems should reveal how to build a user profile according to various users and how to activate the user profile in order to provide effective personalization [16]. The users are categorized into three categories (Low, Moderate, and High) based on users' background knowledge, preferences, interests to get the right and relevant e-lectures. This will facilitate users to look for what they need and reduces time in searching for relevant e-lectures.
- Useful Content Adaptation Approach: Many user interaction techniques used to display Information in a usable format for specific object types; such as text, image, video, and animations usage to attract the user's attention. An interface can allow users to easily decide and transfer among tasks or objects of interest, and provide notification of which task is in progress
- Interface-Layout Design Adaptation: It is to design layout structure and tailored the layout interface elements to be applied efficiently to access features most relevant to the user's task; in using tables, frames, headings, text appearance, forms, boxes, etc. The user interface layout decision needs to be simple and attractive as possible
- Analysis of Usability Functions and Tasks: it is concerned with. the challenges of how long and difficult the tasks are, and the solution for difficult situations need to be done prior to the development process [17], [18]. The interface should reduce the time used in searching, accessing and downloading educational resources.
- Spatial Adaptation: The navigation through the pages of the Website is depending on the user's assessment and feedback [14]. It is preferred to be consistent and reduce the amount of navigation needed to access the required information.

Adaptive user interface supports visualization services, providing functionality to make decisions about what and how available information can be offered. For an adaptive system, information about an individual user, who behave differently from other users; is represented by user model [19], [20]. The individual differences can significantly impact a user's visualization model. User's information changes as a direct result of interaction with information. It consists of information for long-term and short-term interest depending on temporal characteristics. User modeling or user profiling filters the relevant information from temporal incoming information and compares them with the user profile. User profiles can be categorized as two groups according to their temporal coverage. The adaptations are mainly intended to improve the performance of users [21].

Since the adaptive e-Learning interface is a process where learning contents are delivered to learners adaptively, that is to say, the appropriate contents are delivered to the learners in an appropriate way at an appropriate time based on the learners' needs, knowledge, preferences and other characteristics**.** Adaptive intelligent learning is able to assess student's background knowledge level through randomized and well-selected questions. The student followed the learning path that is proposed by the system and used the system's guidance. The adaptive auto-evaluated questions are used in searching for, selecting, sequencing and retrieving the appropriate lecture for the student [7]. This framework focuses on using semantic categories, where each category refers to real world conceptual entities (i.e. characteristics), so this will improve the user model or user profile and conceptually extend its undesirable static side. Large sets of different e-lectures notifications are gathered for each category. They will contribute to develop better user profile and to improve users' performance in solving their tasks.

The adaptive interface provides a list of *links* to all educational e-lectures and each link is augmented with an *adaptive icon* that visualized the status of the educational e-lectures that are adapted to the current state of the student's knowledge and history of past interactions. These icons help students to:

i. Distinguish new e-lectures from examples that have already been partially or fully explored in the past
ii. Distinguish e-lectures that are ready to be explored from e-lectures that demand prerequisite knowledge the student lacks.

IV. Adaptive Knowledge-Based Visualization

It is to personalized access to repositories of educational resources in helping students to determine resources that match their individual goals, interests, and current knowledge. Adaptive Knowledge-based Visualization for determining repository materials is done using *similarity-based visualization* technique.

As a first step, it is necessary to classify the users into one of predefined groups before the adaptation can be performed; the users are classified by their interaction patterns and background knowledge about the learning subject. The background knowledge is assesses according to the answers of randomized and well-selected questions in adaptive intelligent learning phase. This classification activated the adaptations to the e-learning system. Therefore, the route and user interface to the intended e-lecture is different from one user to another.

The adaptation of user interface is activated by a set of rules. For suitable adaptations, the system can extract new information about student background knowledge and refine some of the cultural knowledge through observation of the user's interaction with the system. The user; who is new to a system, needs to initially give the required data in a short questionnaire provided by an application. The currently live country can be predicted from the IP address of the user's computer on Web. The data is augmented to student's cultural data and student's personal data record files in student database.

Suppose we have a collection of *N e-lecture documents*. There are sets of well-explained items that appear together in the documents of e-lectures, and how frequently they are used in searching specific e-lecture; these "frequent item-sets" are considered as the characterization of the data that we seek. Often, e-lecture document data seems like a collection of term sets. Each lecture is characterized by a two-dimensional vector, and the value of each dimension corresponds to the number of times that term appears in the lecture. The terms in the e-lecture document are represented as two-dimensional array as follows:

TABLE 1: Two-dimensional representation of terms of each lecture

	$Lecture_1$	**$Lecture_2$**	…	**$Lecture_n$**
$Term_1$	$Term_{11}$	$Term_{12}$	…	$Term_{1n}$
$Term_2$	$Term_{21}$	$Term_{22}$	…	$Term_{2n}$
$Term_3$	$Term_{13}$			$Term_{3n}$
…	…	…	…	…
$Term_m$	$Term_{m1}$	$Term_{m2}$	…	$Term_{mn}$

The frequency of a term in the e-lecture is represented by the number of times that the term '$Term_{ij}$' occur in e-lecture document j '$LecDoc_j$' is calculated as:

$$\mathbf{TermFreq}(\mathrm{Term_{ij}}, \mathrm{LecDoc_j}) = \sum_{i=1}^{m} \mathbf{Term_{ij}} \quad (1)$$

TermFreq(Termij, LectDocj) is defined as the frequency (number of occurrences) of term i in e-lecture document j. Then **TermFreq**($Term_{ij}$, $LecDoc_j$) is normalized by dividing it by the maximum number of occurrences of any $Term_{ij}$ in the same e-lecture document j.

$$\mathbf{TF_{ij}} = \frac{\mathbf{TermFreq}(\mathrm{Term_{ij}}, \mathrm{LecDoc_j})}{\mathbf{max_k}\, F_{kj}} \quad (2)$$

Thus, the most frequent term in document j gets a TF of 1, and other terms get fractions as their term frequency for this document.

The lectures in repository are converted into weighted term vectors. The weights are derived from the calculation of the following equation. The weighted vectors are used later in calculating the similarities of e-lectures that have the same educational lecture concepts and user's knowledge, and to place them in appropriate positions. The weighting equation TFIDF (Term Frequency times Inverse Document Frequency) is used to measure the word importance. The terms with the highest TFIDF score are often the terms that best characterize the topic of the document. It is normally computed as follows [21]:

$$\mathbf{TFIDF}(\mathrm{Term_{ij}}, \mathrm{LecDoc_j}) = \mathbf{TF_{ij}} \times \mathbf{IDF_i} = \mathrm{TermFreqij} \times \mathrm{IDFi} \quad (3)$$

$$\mathbf{TFIDF}(Term\mathrm{ij}, \mathrm{LecDoc}) = \mathbf{TermFreq}(Term\mathrm{ij}, \mathrm{LecDoc_j}) \times \mathbf{log}\left(\frac{|\mathbf{TotalLec}|}{\mathbf{LecDocFreq}(Term\mathrm{ij})}\right) \quad (4)$$

Where:

TermFreq($LeDocc$,T $Term_{ij}$): Number of occurrences of term '$Term_{ij}$' in lecture '$LecDoc$'
LecDocFreq($Term_{ij}$): Number of e-lectures where term '$Term_{ij}$' appears in them.
|TotalLect|: Total number of e-lectures in the repository

V. The Cosine Similarity Coefficients

The objective is to find pairs of e-lecture documents that have a relatively large fraction of their terms in common. The cosine similarity coefficients are used for calculating the similarities of lectures depending on their inner extracted terms. The Cosine similarities measure the cosine angle of the two vectors X and Y, and the outcome of cosine similarities is bounded in [0, 1]; where 0 represents that the two lectures are totally different, 1 represents that both vectors are identical) and and in-between values indicating intermediate similarity. It is a measure of how similar the lectures are likely to be and it is efficient to evaluate a sparse vector [22].
Given two vectors of attributes, x and y, the cosine similarity, $cos(\theta)$, is represented using magnitude as:

$$Cos(\theta) = Sim(X, Y) = \frac{\sum_{i=1}^{n} x_i \times y_i}{\sqrt{\sum_i^n x_i^2}\sqrt{\sum_i^n y_i^2}} \quad (5)$$

VI. Learning Algorithms Using User Profile

Implementing customization action; using adaptive techniques, assists constructing the user model. A particular emphasis must be given to the user interface design and the quality of user interaction. The user model is motivated by a number of observations and requirements. Visualization effectiveness has mostly focused on properties of the data to be visualized or the tasks to be performed.

The adaptive techniques uses short-term and long term modeling. Figure 2 shows the algorithm of short-term and long-term modeling.

A. *Short-Term Modeling*

To qualify the similarity between two text documents, a similarity measure algorithm is applied in a well-studied problem in Information Retrieval. E-lecture relevant text notification is convert into TF-IDF vectors (term-frequency/inverse document-frequency), and cosine similarity measure is then used to quantify the similarity of two vectors, depending on the document representation and the associated similarity measure.

B. *Long-Term Modeling with a Naïve Bayesian Classifier*

Bayesian classifier has become an increasingly popular algorithm in text supervised learning and classification applications. The naïve Bayesian classifier is used as a probabilistic learning algorithm to predict long-term predictors of user's general preferences, which that could not be classified by the short-term model.

Prob(feature| interesting) > Prob(feature | ¬ interesting).
ConvertVectorComponent(TFILF) // Weighting Function
// ***TFIDF is term frequency multiplied by inverse of lecture frequency***
Store(TF-IDF representation) in the user model
{ // ***Quantify the similarity of two vector***
// a. ***Prediction for Short-Term Model for User's General Preferences***
If ∃ **d**: **d** ∈ {Short_Term } ∧ Cosine_Similarity(**d**, unseen) > Threshold_Min
{ // ***Represent User's Multiple Interests***
Rank = Nearest_Neighbor_Prediction(unseen, {short-term })
If ∃ **n**: **n** ∈ {Short_Term } ∧ CosineSimilarity(**d, n**) > Threshold _Max
Rank = Rank * k; where k << 1.0 for known term
}
//b. ***Prediction for Long-Term Model for User's General Preferences***
Else
If ∃ {$Term_1$, $Term_2$, … , $Term_n$}: ∀ Term ∈ {$Term_{11}$, $Term_{12}$, …, $Term_{mn}$}
Such that Prob (Term | Interest) > Prob (Term | ¬

Figure 2. A Pseudo Code of similarity measure for a short-term and long-term model of the user's interests

E-lecture relevant document is represented as Boolean Term vectors, where each Term indicates the presence or absence of a feature. A set of domain specific features, (i.e. Terms that are likely to be indicators and the commonly used ones) are selected manually by domain experts. They are classified into interested and uninterested Terms. Not all the terms that appear in e-lecture document are used as features.

Each category should have a sufficient number *'n'* of features or indicators for category membership, where the probability of interested features > probability of interested features.

VII. Conclusion

- The important characteristics that can make the interface flexible, consistent, less complex, and more practical are addressed.
- Adaptive Knowledge-based visualization for accessing the educational e-lectures in Web-based learning environment is achieved through personalized access to repositories and helping students to find the educational resources that match their individual goals, interests, and current knowledge level.
- The important characteristics; user's preferences, background knowledge level, needs, cognitive abilities, interface layout diversity, and interface structure are identified, those influence the model and make the interface flexible, consistent, less complex, and more practical.
- A framework for visual adaptive for Web-based e-learning system is designed to use a weighting scheme developed under the probabilistic models and artificial intelligence reasoning techniques to provide relatively customized reliable, dynamic and easy to use data, while earlier were providing slow and static data.
- Short-term modeling and long-term modeling of learning algorithms, which are based on similarity-based visualization, are conceptually used to help e-learning users to assess, retrieve the right educational resources, and they facilitate the e-lectures classification according to user's preferences and backgrounds.
- It is reasonable to design user interface for e-learning Website to attract an international audience to meet the needs of users' preferences interaction styles and knowledge levels and automatically compose personalized interfaces.
- The adaptive model improves the performance, as well as the user satisfaction of a personalized Website compared to a non-adapted version of the same site, which reflects the users' subjective perception of the interface.

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About Author:

Dr. Nedhal A. M. Al-Saiyd. She got her B.Sc. degree in Computer Science from University of Mosul-Iraq in 1981, M.Sc. and PhD degrees from University of Technology, Baghdad-Iraq in 1989 and 2000 respectively. She is an Associate Prof. at Computer Science Dept., Faculty of Information Technology, in the Applied Science University, Amman, Jordan. Her research interests include Software Engineering, Ontology Engineering, Intelligent Systems, User Authentication, Security and Speech Processing.