Intelligent Exploration System - An Approach For User-Centered Exploratory Learning

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1. Abstract

The following paper describes the conceptual design of an Intelligent Exploration System (IES) that offers a user-adapted graphical environment of web-based knowledge repositories, to support and optimize the explorative learning. The paper starts with a short definition of learning by exploring and introduces the Intelligent Tutoring System and Semantic Technologies for developing such an Intelligent Exploration System. The IES itself will be described with a short overview of existing learner or user analysis methods, visualization techniques for exploring knowledge with semantics technology and the explanation of the characteristics of adaptation to offer a more efficient learning environment.

Keywords: *Intelligent Tutoring Systems, Information Visualization, Knowledge Discovery, Knowledge Exploration.*

2. Introduction

The recent technological developments in the area of social-networks and user generated content have already changed the learning behaviour of any learners. The exploration of knowledge through the world-wide-web using different content-provider, e.g. Wikipedia or IEEE Xplore plays a key role for researcher, students or knowledge workers. The usage of users' knowledge or user generated content is a self-evident process within the working or learning workflow. Different approaches try to face the mass of information given in the WWW to support a more effective learning process, whereas semantic-technologies are a promising approach for organizing the knowledge. The formal knowledge descriptions like Ontologies used by Semantic Technologies only provide approaches to describe knowledge within a given and predefined knowledge-domain. The graphical representation of these domains provides another opportunity to explore the pre-engineered domain, whereas the learner with his individual learning aptitudes, learning behaviour and interests is not involved in the process of knowledge representation.

The following paper describes the conceptual design of an Intelligent Exploration System (IES) that offers a user-adapted graphical environment of web-based knowledge repositories, to support and optimize the explorative learning. The paper starts with a short definition of learning by exploring and introduces the Intelligent Tutoring System and Semantic Technologies for developing such an Intelligent Exploration System. The IES itself will be described with a short overview of existing learner or user analysis methods, visualization techniques for exploring knowledge with semantics technology and the explanation of the characteristics of adaptation to offer a more efficient learning environment.

3. Exploratory Learning

Discovering and exploring our environment for gathering information and knowledge, is the easiest way of learning. Since our childhood we are learning by discovering and finding our environment. When a child plays with things and drops them out of his pram, he learns a fundamental physical law: that the item drops to the ground [17].

While the school education in past preached ex-cathedra teaching, the changes in the characteristics and usage of internet, provides the opportunity to explore the teaching lectures in the internet [12]. Every student in lower and higher education uses the different multimedia possibilities of the internet for learning and exploring the world's knowledge. The Net-Generation [19] gathers knowledge form user-generated content providers, e.g. Wikipedia, Youtube or explores using a search machine. This behaviour is a self-evident process, which came up with on the one hand technological changes of the internet and on the other with the need of knowledge in every domain. While knowledge itself seems to expire, cause newer and more precise information are available.

Beside that the exploration of knowledge is one of the most important ways to adopt knowledge; contemporary findings [17], [11] demonstrated the importance of the individual's or learner's own activity, interest in learning and the importance of pre-knowledge. Through perceptions, experiences, and active mental work, the memory traces corresponding to these models grow and strengthen, and knowledge structures are formed [17]. Furthermore, when considering the acquisition of expert skills in some area, the organization of domain-specific knowledge structures and the learner's own active involvement and interest become even more important. The differences between the learners and their level of precognition can therefore be very different, while they interact with the same computational systems for learning the same.

The human individuality is weakly considered in today's learning systems. The learning systems are mostly designed to be used from everybody or from persons within a specific knowledge-domain. Research on knowledge-based learning system (formerly Intelligent Tutoring Systems) (see [1], [3], [4], [8] and [12]) and Intelligent and Adaptive User Interfaces have already done first steps to realize bridging the gap between the individual pre-knowledge and aptitudes of learners and the presented knowledge. While the most systems only consider the content, the way of knowledge presentation or visualization is merely considered.

3.1 Intelligent Tutoring or Knowledge-based Systems for Exploring Knowledge

The following subsection gives a short outline about existing knowledge-based systems, whereas in all of the following works the term "Intelligent Tutoring System" is used, somewhere with the add on Intelligent Tutoring as agent.

A very interesting approach is described in [12], where the Intelligent Tutoring is called Adaptive

Tutoring. The system is embedded into a Virtual Leaning Environment, the so Virtual Car Dealer [12]. The intelligent or adaptive module is dividing the learner into three levels. The system tries to use the most effective pedagogical approach for the learner, who wants to learn with the system. So first it is necessary to find out which approaches are recommended for which kind of learners.

For the learners' levelling the approach of DREYFUS is used. For each of these stages, there is one pedagogical approach recommended. For example the Novice can learn more effective, if the teaching system uses the behaviouristic approaches, in this case the learner can always see which answer or action was the right one, he needs strict instructions and detailed annotations. In contrast to the Novice the Expert does not need this kind of instructions it is rather destructive, if a teaching system instructs him that way. He gets bored, feels under-challenged and does not continue with learning.

The following figure shows the five stages of a learner and the recommended pedagogical approach:

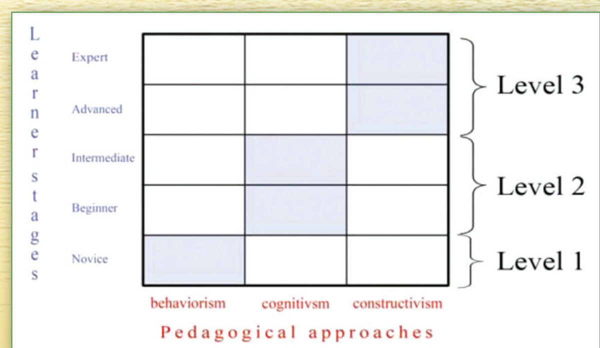

Figure 1: Recommendation for the learner stages [12]

For analyzing the learner the ATS system described in [12] uses three parameters. The first of them measures the time for the different actions done in the virtual world. The time parameter gives an outline of the time needed for each step and can therefore be considered for analyzing the learner. The second parameter considers the actions of the learner. Because the learner interacts in a VLE, it is possible to check the actions and analyze, if the learner goes the right way, the best right way or a way with mistakes. The third parameter is the explicit questioning about the steps. With this procedure the learning system ensures that the learner knows about what he is doing. The following figure shows the parameters, which are used for adaptation:

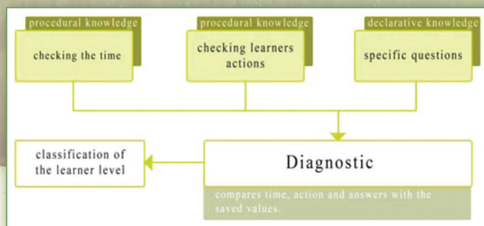

Figure 2: Procedure of categorizing the learner

The adaptation or the tutoring itself is based on the analysis of the system. The system provides the learner with different help-mechanisms and pedagogic approaches. For example the first level learner gets instructions, the second level learner just a kind of "socratic dialogue" and the expert or level three learners get no help. [12]

Another similar approach is described in [19]. The help in this system is provided by hint through an intelligent agent. The learner gets more and more information about the learning stuff within a VLE.

The system has in addition to [12] an approach to use the learning-by-teaching theory. The systems ask question after the learning scenario is finished and the learner has to teach the system. With this procedure a more detailed analysis of the learner is possible, whereas the explorative approach is constrained to question and answers.

The approach presented in [5] detects for example students, who are off-task, e.g. "engaged in behaviour which does not involve the system or learning task". The intelligent tutoring approach is here used for observing the students' behaviour.

All the mentioned systems try to bridge the gap between the learner with their individual learningaptitudes and pre-knowledge and the learning systems. The explorative learning approach are often interpreted as acting in a Virtual Learning Environment, which represents an abstracted and virtual model of the real world where the learner interacts with an avatar as a representative of himself. But the most learners today are investigating and researching using the internet. The procedure of knowledge exploration in the internet is a very self-evident process. Different technologies try to make the internet itself more intelligent. The most famous approach is semantic-web, using ontologies for the description of knowledge.

3.2 Knowledge Exploration Using Ontologies

According to a very early definition of ontology based on the works of Gruber [20] Ontology is an explicit specification of a conceptualization of a domain of interest, here a knowledge domain. Ontology describes with its data structure a specific knowledge domain mainly in concepts (classes). The description is explicit and formal, so the main goal of ontologies is the use and reuse of knowledge in AI-related systems. The formal knowledge description made by ontology opens information visualization systems new possibilities to bridge the gap between a formal language and the human's perception. As ontologies offer more formal specification as only concepts or individuals (objects), the abstraction of ontology is necessary to reduce the complexity. For visualizing ontologybased information the main characteristics can be defined as: concepts, individual and relations.

Ontology describes the knowledge in concepts, which represent an abstracted and formalized set of knowledge classification and can be further described with properties. A concept can contain subconcepts, individuals and relations. Sub-concepts classify the knowledge further in sub-classes, so they describe a kind of taxonomy. An individual is an instantiation of the concept and represent knowledge entities. Relations describe associations between the concepts, and further the association between individuals too. For Example in an ontology exist the concepts "State" and "City", the concepts may have a relation “is a city of” or “is capital of”. An example for their instantiation could be “Germany” (State) and Frankfurt, Berlin (City). The relations of the individuals could be: Frankfurt (“is a city of”) Germany and Berlin (“is a city of” and “is capital of”) Germany.

As the very simple example shows, the structure of an ontology can be very complex. It is possible to navigate and explore knowledge on an abstracted level of concepts or take the individuals into account. The visualization of the whole ontology with all its relations, concepts and individuals confuses the average user and the learning curve is not better than common complex systems.

Ontology is a formal, machine readable description of knowledge, whereas today’s learning processes are not formal anymore. A common scenario of gathering and adopting knowledge on web could be the usage of Wikipedia. The user starts searching for a specific topic and finds an article on Wikipedia. The most users read the main description and scroll down to the different headlines of interest. But the process of knowledge exploration has just begun now. The users find in the searched article hyperlinks to other topics and want to know more. As we made a small evaluation with students, who had to answer a very simple question using Wikipedia, we could see that 18 of 20 students read more articles related to the main one and spend more time with other articles. This is the typical behavior of exploring knowledge.

Ontology-described knowledge has more associations and they are explicit and entitled. The users have the possibility to navigate through the relations and learn while interacting through a graphical system of knowledge. They explore by using the ontology structure and gain more knowledge, without losing the real context.

4. Intelligent Exploration System

To provide a system that fulfils both the explorative learning approach through the internet and the heterogeneity of the learner, a system is required that offers an environment for exploring the web’s knowledge and considers the pre-knowledge of the learner. The following section will introduce the conceptual design of a system that uses the user navigation history for visualizing him the required information.

4.1 Learner Analysis

In recent years different statistical models were used to analyze user’s behavior and to capture the needed user information for adapting the user interface.Getoor et al. [21] predict the interests of users with Probabilistic Relational Models (PRMs) to filter products of a commercial internet platform. For this task they build a PRM from the interactions of every user and group similar models to realize collaborative filtering. Noguez et al. [22] use PRMs for an intelligent tutor system that assists students during the work with a virtual laboratory. The laboratory simulates a mobile robot and allows experiments regarding mechanical design, sensors and control sequences. The interactions of a student serve as input for the PRM that determines the level of knowledge. With this information every student is categorized in one of three categories (novice, advanced learner and expert). The information about the student is used to generate individual hints for the improvement of the learning process. Beside the dependency structure, for the usage of PRMs a relational schema is needed. This necessity implies a higher configuration effort compared to BNs and thus the appliance of PRMs in different application scenarios is complicated and time-consuming.

Markov Models are used to describe a sequence of events. They can be used to calculate predictions of interaction events and allow the quantitative analysis of interaction events. For example Guzdial [23] uses Markov Chains to capture usage patterns from users of Emile (an application for the creation of animated simulations). The application is divided into five parts. Every interaction event is tagged with its associated part and used as input for the Markov Chain that models the transitions from one part of the application to another. With the calculation of the steady state vector from the transition matrix of the model, Guzdial is able to infer quantitative statements about the usage of Emile. Anderson et al. [24] introduce Relational Markov Models (RMM) and use them for the automatic adaption of web site navigation to minimize user's effort in reaching their goals. The RMM uses a relational structure of the web site to predict user's behavior even in web sites that the user never visited before [24], [26].

The LEV- and KO-Algorithm proposed by Künzer et al. [25] calculate predictions of interactions by the search of recurring similar (LEV) or identical (KO) sequences of interaction events. Künzer et al. use the algorithms for an intelligent help system which is integrated in Active-UI (Autonomous Production Cells Multimodal and Adaptive User Interface). The application allows the control of laser exudation processes. The integrated help system is divided in an intelligent tutor and an adaptive help system. The first one shows the predicted actions including assistance and allows the direct execution of predicted events. The adaptive help system is passive in contrast to the intelligent tutor. It doesn't contain links for the execution of the predicted actions. Künzer et al. evaluated the prediction quality of the two algorithms by comparing them with other prediction algorithms. The results show that especially the KO-Algorithm offers the best prediction quality [25], [26].

The different prediction methods described here are often used in intelligent and adaptive user interfaces or in recommendation systems. The learners' interaction can and should be considered for recommending and visualizing information. The visualization of knowledge plays a key-role for the explorative approaches. In the following subchapter different visualization techniques will be presented which ecplicitely developed for knowledge exploration using semantic-data structure.

4.2 User Interface and Visualization for Knowledge Exploration

As described in section 2.2 ontologies and semantic structures provide new possibilities for visualizing information respectively knowledge. There exist different approaches for exploring knowledge through a graphical representation of knowledge. In this section two different visualization methods will be presented with the goal of identifying the adequate visualization technique for recommending information by an Intelligent Exploration System.

In [27] the SemaSpace (formerly SemaVis) visualization tool is described as a tool for the visualization of knowledge spaces, modeled as ontologies (concepts, instances, relationships etc.), supporting different aspects, e.g. thematic, co-occurrences, spatial, clusters, or configurable domain-specific representations. The basic approach for the semantic visualization is to consider the different pedagogical approaches and knowledge spaces issues to visualize semantic information. Furthermore, SemaSpace offers the possibility to define the graphical representation for knowledge items within knowledge spaces. It will also help to support the users with an additional cognitive approach. The both features graphical metaphor from real life and the usage of graphical representation e.g. icons will help to reduce the cognitive load for the users and allow user to focus on knowledge spaces and knowledge items to navigate through the knowledge spaces. ([27], [28])

Following a screenshot of SemaSpace is figured with its different knowledge spaces:

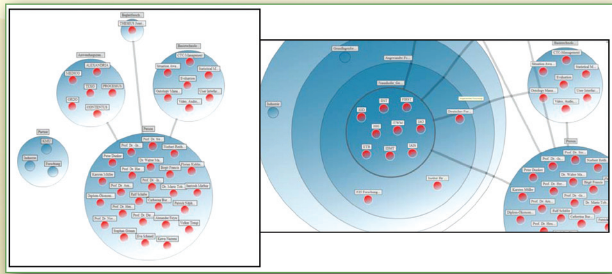

Figure 3: SemaSpace – Visualization Screenshot

Another semantics visualization approach, the so called SeMap is described in [15], which subdivides the semantics structure into an abstracted level of ontology concepts, where the hierarchical structure of the knowledge domain is visualized. Therefore SeMap uses Shneiderman's Treemap approach [15] combined with the wide-spread visualization technique Treeview [15], whereas SeMap is built up in contrast to the Treemap by the navigation of the user. The user plays an active role in the buildupprocess. He navigates through the hierarchy of the semantics for doing any process with semantic data, for example for searching a specific content. By navigating through these structures he gets more information about the searched content. The user gets information about the higher level meaning of a term, e.g. he searches for the document containing information about usability, the user gets higher-level information about his search. With these information the user is able to gather more knowledge, e.g. he is able to gather the information that usability is a research area of both psychology and computer sciences. So the implicit information he gets here is that usability as term exists in different scientific disciplines. [15]

This effect can be amplified with visualizing the first or second level of semantics relations; by using graph-layout algorithms. This is the most detailed way of presenting implicit knowledge, without focusing on imparting knowledge. The user gets the first semantic relations of a given content to other contents and is able to view similarities and differences.

The combination of SeMap as a visualization of abstract concepts containing higher level information and a graph-layout algorithm which visualizes the semantic relationships offers an adequate and fast way for exploratory interacting with knowledge. The following figure shows the mentioned combination of these two visualization techniques, SeMap and SemaGraph [15]:

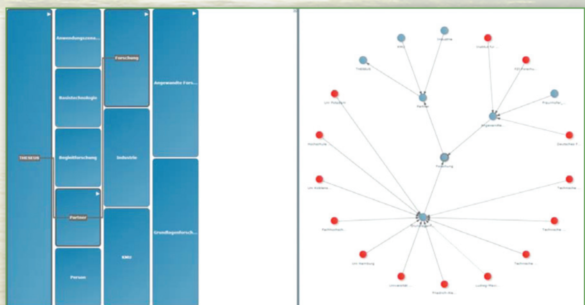

Figure 4: SeMap for Visualizing knowledge [15]

4.3 Adaptation to the Learner

The usage of semantics visualization techniques offers new ways for interacting with knowledge for exploring the internet. Beside a graphical interaction and navigation through knowledge the aspects of intelligent tutoring systems play an important role for conveying knowledge effectively. For specifying knowledge assets that are more or less important for a learner, user interaction analysis methods, described in section 3.1., could be used. With the usage of recommendation systems and interaction analysis systems the learners' pre-knowledge could be considered. For example, if a user search in the semantic web for the term "usability", the systems considers the history of the documents he opened and read in the past. Reading a document can be measured with time-capturing methods, which analyses the duration of an opened document combined with the interaction, e.g. scrolling down a document. Other methods for analysing the learners' behaviour like the off-task measurement [5] can be used too for ensuring that a document was read. If the system has enough "interaction history" of the learner, it can offer prior the information that is within the domain of interest. So a search for the term "usability" opens in a concept hierarchy two domains of interest: "Computer Schience" and "Psychology". The two concepts are weighted different for each learner. If the learner's interaction history bears that "Psychology" is the domain of interest, the related semantic concept is highlighted for this individual learner and further sub-concepts and instances will be shown. Whereas the learning items in the area of Computer Science do not disappear, as usual in recommendation systems. The learner has further the opportunity to navigate through the non-relevant concepts and explore the knowledge beside his area of interest.

The following figure shows the explained scenario, whereas the highlighting of the domain of interest can be further indicated by size, order and color of the knowledge concept and asset:

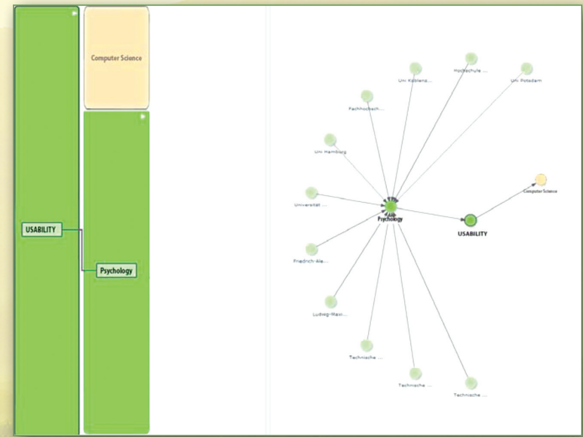

Figure 5: Adaptation of SeMap

In figure 5 the intelligent exploration indicates that the most relevant dosuments for the learner are placed under the concept “Psychology”, where he gets suggestions for different documents and multimedia files. Further he gets the information that there exist other documents in the area of computer science. If the learner wants to know more about usability as a discipline of Computer Science, he has still the opportunity to navigate through this concept. The system will register this behaviour and will give him in his next session other suggestions, based on his behaviour.

5. Conclusion

The paper described the methodical design of an Intelligent Exploration System, which uses semantic web technologies and recommendation system to visualize knowledge networks in an adequate way. The main target of such a system is to consider the pre-knowledge of the learner and provide him the best-fit next steps for learning. The learning method supported by the IES is exploratory learning using the semantic web resources.

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