Deriving Action-based Semantics from Learning Repositories

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Abstract-- **Motivated by recent developments in Category theory, we have designed a generic virtual layer that overlays repositories of learning objects. Agents embedded in this layer observe traversals from both the repository and the user perspective, and support the inference of dynamic semantics based on actual usage. We will experiment with the dynamically generated metadata with the goal of enhancing users' navigation and discovery experiences.**

Index Terms--**Multi-Agent, Learning Objects, Intelligent environment, User pathway, Recommender Systems.**

I. Introduction and Motivation

The learning community has adopted the idea of repositories of learning objects with gusto. In Australia, for example, "… all States, Territories and the Commonwealth of Australia are collaborating in this Initiative-The Le@rning Federation-to generate, over time, online curriculum content for Australian schools. " Our concern is that coded metadata, hard indexes and search mechanisms will provide insufficient support for content users to explore and discover useful materials in very rich and complex repositories. We have designed a generic, virtual layer that sits over repositories and collects information about users' traversals. Inspired by the Prototype Category theories of Elinor Rosch [11] and George Lakoff [12], we intend to experiment with the information derived from these traversals to attempt to infer action-based semantics about the repository. For example, we may 'discover' communities of users and categories of content that are not explicit in the indexes; We will use this derived metadata to inform user profiles and more generally attempt to enhance the experience of the users, content providers and site managers in navigating, discovering and managing the material in the repository.

This paper describes the architecture of this 'business intelligence layer'.

II. A Case Study with Learning Objects

The multi-agent architecture presented in this paper is designed to address the problem of making effective use of very large repositories of learning objects. In this section we describe the case study in which this problem appears.

Technological advances in the past few years, particularly in the area of online delivery and e-learning, have inspired changes in the way educational materials are designed, developed, and delivered to teachers and students. A major shift in educational materials development has occurred where there is a move away from the traditional method of developing courses in an integrated way to accomplish a learning objective to one that is based on the use of individual building blocks or bite-sized "learning objects" [8]. This approach resembles what Wayne Hodgins, Director of Worldwide Learning Solutions, has called the Legos™

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approach. In the same way that Legos™ building blocks can be used to build a variety of structures, so too learning objects can be used by lecturers, teachers and others in creative ways to build courses which meet different learning outcomes. The theoretical underpinning is that instead of thousands of people wasting time "re-inventing the wheel", a learning object once constructed can be re-used and shared. Steven Downs [9] has argued that the economics of sharing learning objects are relentless.

This new approach has resulted in the establishment of a large number of learning object repositories both within Australia and overseas.

While theoretical underpinnings of learning object repositories are difficult to challenge, a number of issues relating to their establishment still need to be researched. Our project will address major problems/issues, such as the lack of consultation/analysis of user needs in the creation of repositories and inadequate resource discovery tools. It has been reported that many of the learning repositories are difficult to use.

We will try to address these problems:

• by undertaking user needs and usages analysis, and by using the data collected by the multi-agent component (see fig.1);

• by facilitating access to the plethora of content repositories and to address the problems of locating, exploring and manipulating learning resources expertly and creatively;

• by using the Learning Object Exploration System, cross-domain searching software and profiling systems to automatically match the needs of users with the appropriate learning objects;

• by using "intelligent" agents to "remember" frequently used and relevant resources and to inform users through presenting more intelligently guided pathways within that virtual environment.

The project will deliver an intelligent Learning Object Exploration System capable of identifying the needs of teachers, lecturers and course builders. This "intelligence" will be based on "profiling", extensive user analysis and resource assessment, and the construction of an "intelligent" agents to provide appropriate feedback.

The development of an intelligent learning architecture incorporates:

- the ability to actively collect and access a wide range of content repositories
- substantial improvements in the usefulness of learning objects within any given repository leading to enhanced exploitation of learning materials.
- the provision of enhanced feedback for the better management of content repositories.

III. Multi-Agent Architecture

In this section we describe this architecture. An overall view of the architecture is depicted in Fig.1.

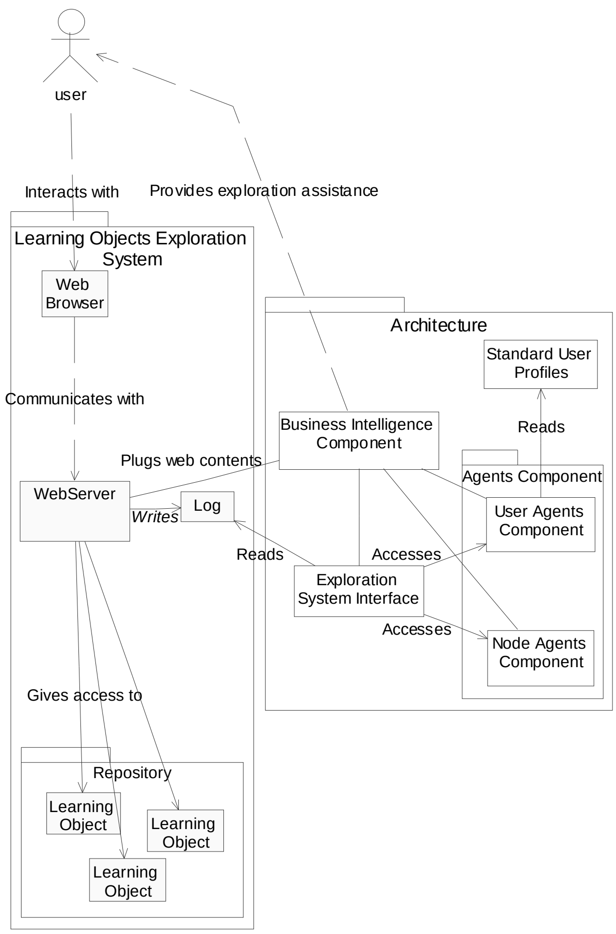


Fig. 1. Overview of the whole system

The prototype is based on an agent infrastructure and agent framework developed in C#. The infrastructure supports multi-hosts distribution via .Net's remoting and MSMQ. Persistent data like profiles is stored in a SQL database on demand and accessed through ADO .Net.

A. *Learning Object Exploration System*

The architecture is designed to be plug into layered over existing repositories of Learning Objects. The system provides access to repositories through a web server. Users simply explore the repository with a web browser and view the Learning Objects as web pages.

The system is linked to the architecture through output and input points on the web server. The output point is a simple server log. For each access to a Learning Object, the log is classically required to record a user identifier (a static IP address for instance), an identifier of the Learning Object and the date and time.

The input point consists in adding web content generated by the architecture to the web page that is viewed by the user.

B. The Agent Components

User Agents Component

A User Agent tracks each user of the system. This agent may have references to Standard User Profiles (SUP) that suit its user. In addition, the User Agent is in charge of maintaining a personal user profile. This profile contains information about the user's pathways. The profile is refined over time as the User Agent Proxy informs the User Agent of the user's activities. When a user logs off for a while, his dedicated User Agent terminates. The profile persists independently from the User Agent and it can be stored into a SQL database on demand. It is reactivated when the user navigates again.

Node Agents Component

Node Agents form a virtual layer supplying information about traversals made between nodes. This information can then be exploited by others elements, such as the Business Intelligence Component. Node linkage information is formulated by the traversal of users between nodes. The term "node" is a general terminology used to represent a particular repository artifact. The artifact could be a web page or a relation in a relational database or it could even be more fine-grained such as a field in a relation. In the case study in this paper, a node is synonymous with a unique web page, thus a Node Agent will be associated with a unique node. In the virtual network.

Each Node Agent has the responsibility of:

- Capturing a user's page traversals (destinations). For instance a node agent (A) observes a web page (P). A user (U) accessed page P and then from there accessed a new page (Q). The node agent A must capture the next web page traverse by the user P, which is page Q in this instance.
- Storing the most recent timestamp for each destination navigated.
- Keeping a count on each destination page accessed from the observed page.

The Log Monitor gathers the information above is gathered by analyzing web server log files. Each Node Agent registers its associated node identity with the Log. The Node is then notified whenever a relevant log line appeared in the web server log and 'memorizes' the information.

C. Business Intelligence Component

This component is in charge of elaborating exploration assistance dynamically for every given user involved in exploring a Learning Repository. This is achieved by generating a directed graph representing navigation pathways. The vertices represent Learning Objects while the edges symbolize navigational links. All the pathways have the current Learning Object as origin. The edges hold information about the relevance of the traversal to the link they represent.

Such information comes from 3 sources:

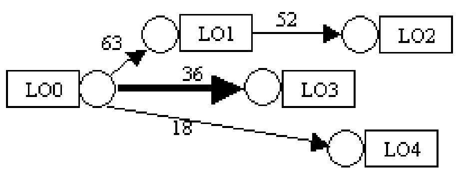
(1) the Node Agents that give an indication of the general popularity of the link,

(2) the SUPs associated with the user, representing users' interest in some categories and

(3) the personal profile of a user maintained by his User Agent.

This information is computed in order to obtain relevancy indicators.

The graph is then formatted to be visualized and sent to the web server for being displayed to the user. A possibility is that the user sees an additional frame on top of the web page by the mean of a plug-in for his web browser. The frame shows a graph whose nodes are actual web links that can be clicked. The graph provides navigation assistance in that the user is proposed relevant pathways. As an example, the graph could be something like this:



In this example, "LOX" is the identifier of a Learning Object; the weight and the length of the edges indicate the general popularity of the link (the bigger the weight, the shorter the arrow) and the thickness of the arrows represents the relevancy of the traversal of the link for the user. This last information comes from the computation of the user profile and the Standard User Profiles (SUP) associated with the user.

D. Standard User Profiles Component

Every Standard User Profile (SUP) defines a category of users. A SUP contains pathway information for exploring Learning Objects that are interesting for the category of users. Administrators of the repository initially define SUPs, either directly or by computing similar user profiles maintained by the User Agents.

When a new user enters the system, he has the option of explicitly selecting SUPs that suit him via a special web page. His User Agent then references the SUPs. Otherwise, a User Agent is automatically created for him and initialized with no

SUP. Later, the User Agent may infer a SUP after some time, thanks to the knowledge of the exploratory pathways of the user.

E. Exploration System Interface

A Log Monitor is in charge of reading the server log periodically. For every line in the log, the Log Monitor notifies the User Agent Proxy and the Node Agent Proxy and transmits the logged information (Fig.2).

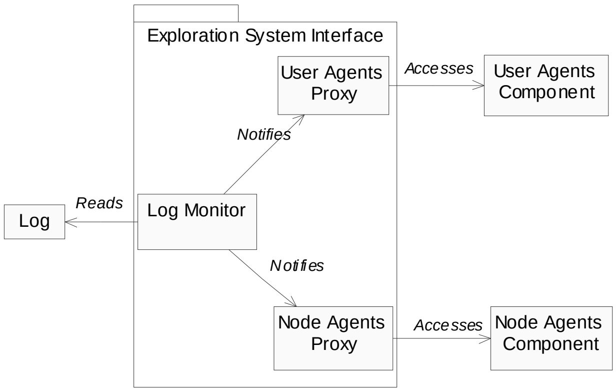


Fig. 2. The Exploration System Interface component

The proxies act as name servers for User Agents and Node Agents. In other words, they know all the agents and their corresponding identifiers, permitting for example access to the Node Agent that manages a given Learning Object. Besides, they transmit the log notifications from the Log Monitor to the agents that are concerned. Thus every User Agent is kept informed of the exploration of the user it manages, and similarly Node Agents keep aware of the navigation of all the users.

When the User Agent Proxy does not recognize a user that is referenced in the log, it means that it is a new user. Hence the User Agent Proxy creates a new User Agent with no SUP.

IV. Related Work

Recommender systems [1] learn about the preferences of users in order to assist them in finding items they are interested in, like books or movies. These systems aim at addressing the problem of information overload, particularly on the Web and in e-commerce. They make use of user profiles that are built either from explicit or implicit feedback from the user. The recommendation mechanism is based on comparing items (content-based), user profiles (collaborative filtering) or both [2].

Our system is comparable to recommender systems in that recommends pathways based on user profiles. Like many recommender systems it facilitates access to information without requiring the user to formulate explicit queries. Additionally, it uses similar techniques such as passive user profiling [3, 4] based on server logs [5] and relies on the notion of categories of users in the same manner as collaborative systems.

However, in addition our system provides assistance based on 3 different dimensions:

- the general community of users,
- categories specific to the user
- and individual user profiles.

Reconnaissance agents like those of the MIT Media Lab [6] help users browse the Web. These interface agents are on the client side to observe the user navigating and generate profiles. When the user reaches a web page, they propose links for further navigation. For example, the well-known Letizia explores all the links on the page viewed by the user in order to eliminate irrelevant links, and then recommends the links that fit best with the user profile.

Likewise, our system provides navigation assistance without interfering with the normal browsing behavior of the user. Also, this assistance changes according to the position of the user in the navigational space. However, our recommendations are not only based on the profile of the user but also on the experience of others.

Also, our attempt to build semantic links can be compared to systems with ontology-based semantics. The idea of the Semantic Web as proposed by Tim Berners-Lee and Jim Hendler is based on coded ontologies permitting software agents to “understand” the relationships between web pages [7].

While we are not seeking to replace ontologies, indexes and other repository metadata, we are taking a diametrically opposite approach to metadata tagging – that is, constructing an architecture that will allow us to experiment with ‘discovering’ rather than coding categories, communities and other interesting semantics based on actual usage.

Our system does not require any ontology since it builds semantic links (infers semantics from links) pragmatically, based on the actual navigation of users. The advantage is that the generation and the maintenance of links are dynamic, hence our system adapts dynamically to any change within the repository.

Although our system is obviously not suitable for navigating the whole Web, it is based on generic principles that make it adaptable to any sort of repository, from a relational database of learning objects or other resources to a local area network of web pages.

V. Conclusion and Future Work

Coded metadata or indexing mechanisms fix the content semantics of information repositories. We believe that we can enhance users' experiences in discovering information in rich repositories by using the mechanism described in this paper to derive semantics based on users' navigations. Of particular interest is the discovery of communities or categories of both information and users, and uncovering untagged aspects of complex objects relevant to the user community. The business intelligence layer described in this paper has been designed as a test bed for such experiments.

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