Exploiting user models to automate the harvesting of metadata for Learning Objects[1]

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Abstract. Metadata on learning objects has a valuable role to play in supporting long term reuse and adaptive selection of learning objects. Unfortunately, there are serious problems when acquiring metadata. This paper explores a new approach to these problems, by exploiting user models. We make use of the PersonisLite user modeling approach to represent both a scrutable user model of the learning object author as well as a scrutable model of the learning object itself. We harvest information available from the environment and from the learning objects themselves and, combining this with the author's user model, we build a model of the learning object. From this, we generate LOM, Learning Object Metadata. The approach has the promise of reducing the effort required to produce learning object metadata as well as providing scrutable, explainable conclusions about metadata values, an issue of particular importance in the case of subjective elements. We describe the application of this approach in Seminar, a system which makes it easy for presenters to capture their presentations and lectures so that these are readily available for viewing on the web.

Keywords. Automated metadata creation, LOM, User models

1. Introduction

Learning environments rely on content authors to provide metadata relating to the educational materials the system stores. This paper details the design and ongoing implementation of the Seminar system developed at the University of Sydney. We describe how extensions to Seminar will provide the necessary metadata for, facilitating future, relevant matches from complex user queries. Our approach is in developing effective techniques to automate the creation and harvesting of presentation metadata.

The architecture of the Seminar system involves exploiting a user model of the Learning Object presenter or facilitator. To manage user models, and resolve between multiple candidate metadata values, the Seminar system utilises the PersonisLite user modeling toolkit [16]. Metadata which is correctly, and most importantly, reliably associated with a captured presentation provides for an indexable and retrievable Learning Object. We use IEEE 1484.12.1 Learning Object Metadata (LOM) as the adopted standard for learning technology present in the Seminar System [12,10]. LOM is a cataloging scheme, consisting of nine categories, used to describe the content of a learning object and its use [13].

In developing the Seminar system, we demonstrate a tightly integrated solution where a presenter need only run a background application that surreptitiously harvests metadata with little or no user intervention. Harvested metadata is complemented with information from a user model to provide both relevant and accurate metadata.

In Section 2 we introduce the components of the Seminar system in its capacity as a Learning Object authoring tool. We also show in this section how the Seminar system provides convenient access

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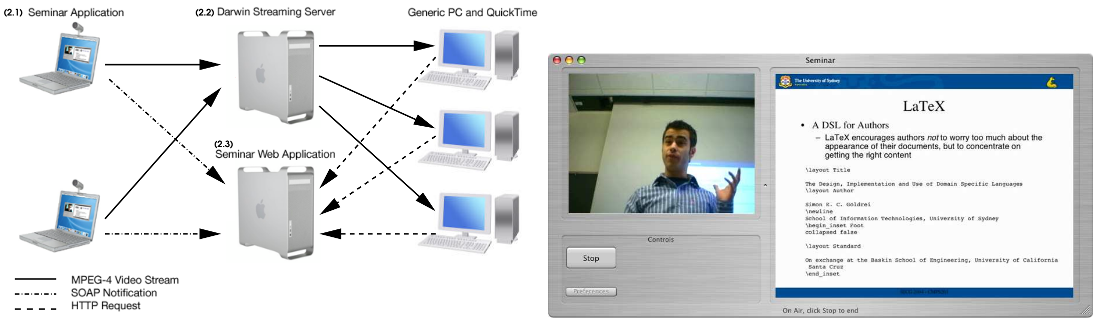


(a) System overview

(b) The Seminar Application as seen by the author (a presenter)

Figure 1. Seminar System

and re-usability from an end user's perspective. In Section 3 we discuss, in an architectural sense, our approach in applying the user model of an *author* in determining reliably the metadata for the Learning Objects that they create. In Section 4 we discuss some of the techniques that we have either already employed or are planning to explore to build such a user model. Finally, in Section 5 we analyse the potential validity of our harvesting techniques and their amenability to elements of the Learning Object Metadata standard [10]. We conclude in Section 6.

2. The Seminar system

Seminar is a three part system for the real-time broadcasting and archival of Learning Objects that can be used in a range of situations such as conference presentations, research group meetings, lectures, or even segments of presentations. Seminar provides a simple, uniform method to capture a computer-based presentation regardless of the software application used in the presentation. Seminar captures the video and audio of the presenter, as well as a motion capture of the computer's main display.

The Seminar System consists of an application written for Mac OS X [1], a streaming media server and a web-accessible database. Presentations captured with Seminar can be viewed on any platform that Apple's QuickTime Player [2] supports. Figure 1(a) shows an overview of nodes that comprise the Seminar system. Also shown are the types of messages, requests and data streams that are transmitted between each of the system components. In the following subsections we describe each of these components.

2.1. Seminar Application

The basic functionality of the Seminar application is the capture of video and audio of the presenter along with a video stream of the presenter's computer display. Shown in Figure 1(b) is the interface of the Seminar Application as seen by the seminar presenter. The resulting three media streams (two MPEG-4 video [9] and audio) conform to Apple's QuickTime format. As a video source, Seminar supports any video capture device that has a corresponding VDIG (video digitiser) [3] component for QuickTime, often referred to as a device driver. Supported devices include FireWire (IEEE 1394 [4]) DV Cameras, some USB web cameras and IIDC [4] devices such as an Apple iSight [5]. Seminar's screen capture is directed at the system's main display; this is not user controllable. The Seminar Application relies on the Seminar Screen Capture component. The Seminar Screen Capture component is installed as a QuickTime VDIG pluggable system component. The Seminar Screen Capture component, responsible for the motion display capture, provides the Seminar Application a video loop-back

(a) Seminar Web Application, showing archive contents

(b) A user view of a Seminar Learning Object as displayed in a browser.

Figure 2. Seminar Web Application.

of the system display. To QuickTime, the Seminar Application, and indeed other video software on OS X, this software-only device driver appears like a system video source like any other.

2.2. Streaming Server

As shown at the top of Figure 1(a), Seminar interacts with the Darwin Streaming Server [6] from the open source Darwin project [7]. The streaming server is used to reflect (rebroadcast) the three streams to requesting QuickTime players on a network. Typically, the Seminar application is configured to uni-cast directly to this server. The node providing the Darwin Streaming Server, and maintaining the Seminar archive, is also responsible for servicing on-demand streams from the archive. This is shown as the three solid arrows at the right of Figure 1(a), representing delivery of separate uni-casts to the three systems.

2.3. Seminar Web Application

The Seminar Web Application, shown in the lower middle of Figure 1(a) is accessible through a web-browser, and provides a publicly accessible interface for listing live, scheduled and archived seminars. It facilitates users joining live seminar broadcasts or watching archived seminars on demand. The interface for the Seminar Web Application is shown in Figure 2(a). In this screen-shot we have listed five archived seminars (each being a Learning Object). To view a seminar, the user, a learner selects the seminar title which links to the on-demand playback, as indicated by the three broken lines at the right of Figure 1(a), each representing a connection to the Seminar Web Application.

The Seminar Web Application, dynamically generates an appropriate SMIL [8] document when clients request to join a broadcast, or when clients request a seminar on demand. The layout of the resulting SMIL document can be altered by modifying a system template, the default template when rendered is shown in Figure 2(b). This is the view of the learning object from the user's perspective.

It should be noted that typically one would not need to deploy the Seminar Web Application on a machine that is used solely for seminar capture.

3. Harvesting metadata for Seminar Learning Objects

Seminar's initial goal was as the authoring tool described in Section 2. To support categorisation and searching within the archive, the system needed to also harvest metadata about each seminar. It was our goal to explore techniques for automatic generation while also overcoming the issues of metadata relevance and correctness as identified, for example, by Duval and Hodgins [12]. The LOM document generated by Seminar describes the educational content of the Learning Object as well as the aspects of the object's creation, such as author, times of modifications, revisions and technical requirements. Before detailing our architectural design for harvesting Learning Object metadata automatically, we discuss the key motivational factors for our approach.

Element relevance

To provide effective searching of Learning Objects in a repository, and return to the user relevant materials, Learning Object authoring tools need to provide metadata that is not only reliable but also *well suited* to the particular Learning Object and its content domain. Many implementations of the LOM standard [15] have identified that some elements are more directly applicable than other elements. These implementations therefore provide only a subset of the standard which can be thought of as a limitation on the description scope. Mohan and Brooks in [13] contend that the varying scope of individual elements "threaten to cause considerable interoperability problems". We propose to explore an automated metadata approach that operates based on the relevance of an individual metadata element for a particular domain of learning. Once aware of the level of relevance, the system can determine if the element's inclusion in the description is necessary and worthwhile. An automated approach that ignores this approach may describe the Learning Object with superfluous, irrelevant or in a worst case inaccurate metadata.

We believe that the use of an author's user model will support scrutable processes for inferring metadata. If sufficient evidence exists in a user model in support of an individual LOM element then the inclusion of that element in the Learning Object description is indeed relevant.

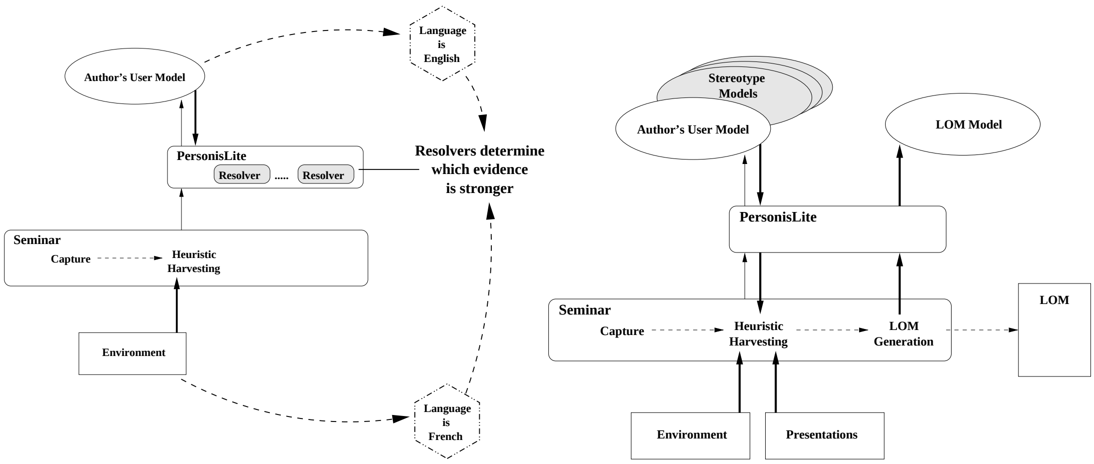
Consider a simple example, where our author's user model provides a lot of evidence that our author has a background in "16th Century France" (perhaps they have previously authored a paper with that in the title). Yet there is only superficial, heuristically harvested, evidence from the environment that this Learning Object is on "16th Century France". Then, regardless, the system can with generally good reliability include automatically, say, the General.Coverage element with the value "16th Century France".

Element subjectivity

We agree with Duval and Hodgins in [12] that the subjectivity of metadata elements is a feature and not a problem. A LOM modeling approach, enables for the model's evidence to be considered or weighted differently under different circumstances. Consider the scenario where students in computer science recommend "Introduction to programming in Python" whereas students from the business school may not find that particular learning object as relevant. In this case, we would like to consider this subjective evidence differently.

Effort to add metadata

A major criticism of the LOM standard is that content authors are unwilling to invest the considerable effort to first determine which LOM elements are relevant and then add all the metadata to their Learning Object [14]. The amount of effort that is required is a real impedance for authoring tools like Seminar, which are designed to be used in what Duval and Hodgins [12] describe as an "artisanal" setting. To illustrate this, consider where Seminar is used in day-to-day teaching, and the effort required for an end user to verify that all the description elements are correct. The solution that Duval and Hodgins proposed is for automatic techniques for harvesting metadata. Also proposed is the use of a template of re-usable metadata. Building on this previous proposal, of a heuristic approach combined with a re-usable template, the Seminar system first exploits a *user model* of the author as an initial source of evidence to infer values for metadata. We now detail the architecture of such an approach.



(a) The role of Resolvers in Personis

(b) Exploiting a user model to harvest metadata

Figure 3. User model architectures

3.1. Architecture

In the Seminar system we exploit a, possibly pre-existing, user model to accurately populate those LOM elements that are relevant to the Learning Object authors' typical teaching patterns. The premise is that a user model defines not only the characteristics of, say, the author's language and perhaps biographical details but more significantly the user model also reveals relevant metadata about, for example, the author's field of expertise.

Currently the LOM standard does not allow for the *sources* of LOM elements values to be stored. We are not suggesting here that such sources should be stored in a metadata collection. Rather the relative reliability of such sources should be somehow scrutable. When authoring a Learning Object we would like to employ a mechanism, that if a particular source is unavailable, unsuitable or unreliable it is omitted from the LOM. This omission can be for one of two reasons; either the data is simply unattainable, or it doesn't meet some level of confidence.

To achieve this goal of reliable harvesting of metadata, the Seminar Application utilises the PersonisLite [16] user modeling toolkit. For each element defined in the LOM, PersonisLite is instructed to determine if the user model can satisfactorily *resolve* some attribute of the user. Resolvers are application definable components in the PersonisLite toolkit. Their responsibility is to interpret multiple, possibly conflicting and candidate, pieces of *evidence*. Evidence in this context are candidate LOM element values. Seminar provides PersonisLite with a set of predetermined and appropriate Resolvers for each element in the LOM standard. Figure 3(a) shows an example scenario, where harvested metadata from the environment or presentation software provides evidence that the Learning Object is in French, where the user model suggests the the Learning Object is in English. Such a scenario can arise if say an English speaking teacher is presenting in France.

4. Building the user model

In order to provide reliable and suitable metadata for Learning Objects, using the mechanism described in Section 3.1, the Seminar system exploits a user model. The purpose of the user model, as previously mentioned, is to provide accurate LOM element values from multiple sources of candidate evidence. From a user model Seminar can resolve metadata about many LOM elements, such as the Learning Object author, affiliations and area of expertise.

Alternatively, should no user model exist, the Seminar system defaults to a *stereotypical user model* which provides general evidence to resolve LOM element values. For example we illustrate the stereotypical model as follows: the Seminar system is deployed in the Music department at the University of Sydney. The stereotypical user model would provide evidence that Learning Objects authored in this environment are:

- Aimed at a tertiary level audience:
  Education.Context : "higher education"
  Education.TypicalAgeRange : "18-"
- Authored by the Music department:
  LifeCycle.Contribute.Role : "content provider"
  LifeCycle.Contribute.Entity : VCard for Music department, University of Sydney
- The location is the University of Sydney and
  Technical.Location : "http://www.sydneyseminars.com"
- The subject discipline is Music:
  General.Coverage : "Music Theory"

To supplement, either a default user model or a pre-existing user-model, Seminar harvests a number of additional sources in a heuristic manner. The metadata sources that have been used in the development of Seminar, producing element values that seem promising, along with other possible sources are:

- **Presentation software** (the Learning Object itself): Slide content; Presenter's notes; Keywords: format, authors, title as recorded when editing
- **Operating System**: Default language; Time zone cities; Full name of user
- **Author's web page**: Author's biographical background; Presentation abstract(s)
- **Seminars** (the captured media): Media format details; Duration

Resolvers supplied to PersonisLite determine whether metadata harvested heuristically by Seminar or pre-existing in the user model are to be used for the LOM element values. By combining harvested metadata with either a stereotypical or a pre-existing user model PersonisLite and Seminar are able to generate automatically LOM in addition to providing a more comprehensive and re-usable user model. Relevancy and accuracy is governed by the quality of the user model. This process, resulting in LOM document generation, is presented in Figure 3(b). In this diagram, we see that Seminar harvests candidate metadata from the seminar capture, the environment and the presentation software shown in the bottom left. Harvested data is contributed to the author's user model, shown in the top left, as candidate evidence allowing PersonisLite to resolve each element value. Resolvers in the Personis system deem which candidate evidence is more reliable. Once each element has been resolved Seminar can generate the LOM document, shown middle right. PersonisLite maintains a persistent LOM model, shown in the top right, with all the candidate evidence for future revisions of the Learning Object. The LOM model can be use to explain the process used in gathering the metadata.

With Figure 3(b) now in mind, consider the scenario, where Seminar heuristically determines who the author of the Learning Object is. One such method is to harvest from the environment (operating system) the currently logged in user, and locate their user model. The author's user model provides evidence that our author has a background in "France during the middle ages." In addition, the presentation software provides, more substantial evidence (than provided by the user model) that the title is "16th Century France". This introduces some contention, as to which is the more reliable value for **General.Title**, which a Resolver will need to evaluate. One of the stereotypical user models provides evidence the author is employed as an educator at a tertiary level and at the "University of Sydney" providing values for **Educational.TypicalAgeRange** and a **LifeCycle.Contribute** entry. Finally, the system's (say, Mac OS X) Address Book facility provides a VCard [11] suitable for a separate **LifeCycle.Contribute** entry for the currently logged in user. By combining all this information using the Personis user model approach, the system is able to resolve the Learning Object title as "16th Century France" (title in this example was the only element in contention). In addition Seminar using Personis is able to generate a more complete LOM model, with supporting evidence for each element, that can be used to generate the final LOM document.

Src	Element	Amenability
SA	1.1 Catalog & Entry	The Seminar Application always maintains the URI for the Seminar Web Application archive.
PS	1.2 Title	The presentation software can offer this value simply as title metadata.
PS	1.2 Title	More reliable than the title metadata, is any heading styled text on the first slide.
Env	1.3 Language	The operating system can return the current locale default language.
UM	1.3 Language	Language evidence from the User Model is preferable over the operating system locale.
PS	1.3 Language	The most reliable source of language evidence is the metadata from the presentation software.
UM	1.4 Description	Author's bio usually provides areas of expertise, which relate to the Learning Object description.
PS	1.4 Description	Heading text from each slide, providing an 'overview'
UM	1.6 Coverage	Combining expertise from the UM and the resolved Title (1.2) to derive common terms. example: UM expertise: farming, agriculture, sustainable development & Title: "Farming in 16th Century France", Then coverage should be: "Farming".
Env	1.6 Coverage	The time-zone city such as "Sydney/Australia" is least preferable.

Table 1. Effective sources of metadata harvesting: General category.

Key: SA - Seminar Application, PS - Presentation Software, Env - Operating System Environment, UM - User Model(s)

5. Amenability of metadata to LOM elements

In this section we provide some analysis of the potential validity of harvesting metadata from the sources previously presented in Section 4. We summarise in Table 1 how amenable each of the sources is to the appropriate element in the LOM standard. In this table we present only the analysis of one category, the General category, from the LOM standard due to space limitations. The General category is provided here as it was thought to be the most widely familiar and therefore useful for discussion. A technical report will, by the time of publication of this paper, detail our approach to the full standard. As an example of how to interpret Table 1 consider the last example, the Coverage element. If the Resolver for the **LifeCycle.Coverage** element, in Personis, has evidence of:

- The author's experience: "farming, agriculture, sustainable development" yielded from the user model as well as
- The title, as harvested heuristically by Seminar (possibly from the presentation software): "Farming in 16th Century France"

Then it can resolve (by deriving common terms used) the coverage as simply "Farming". The Resolvers in the Personis system implement the order of preference logic that is detailed in the rightmost column for each element.

6. Conclusion

This paper proposes a novel approach to the harvesting of Learning Object metadata by initially exploiting a user model of a Learning Object's author. We have described the architecture of the Seminar system which combines heuristic metadata harvesting techniques with either a pre-existing or a stereotypical user model. The paper describes how the Personis user modeling toolkit uses a resolver mechanism to choose amongst candidate LOM element values available in a user model.

The user model approach is both promising in its effectiveness and suitable to harvesting Learning Object metadata because of the strong relationship between a Learning Object's author and the content. The Personis user model approach is particularly advantageous as it is able to capture over time element values that would otherwise be difficult to harvest only at the point of Learning Object creation. Overall our preliminary work seems to indicate that as the quality of the author's user model increases, the accuracy of metadata increases while the scope of description narrows to those elements that are most relevant.

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