The ALOCOM Framework: Towards Scalable Content Reuse

Katrien Verbert[1], Xavier Ochoa[2], and Erik Duval[1]

[1]Dept. Computerwetenschappen, Katholieke Universiteit Leuven
Celestijnenlaan 200 A, B-3001 Leuven, Belgium
{katrien.verbert, erik.duval}@cs.kuleuven.be
[2]Escuela Superior Politécnica del Litoral, Campus "Gustavo Galindo"
Guayaquil, Ecuador
xavier@cti.espol.edu.ec

Abstract. This paper presents a framework that enables flexible content reuse. Unlike the usual practice where document components, such as images, definitions, text fragments, tables or diagrams, are assembled manually through copy-and-paste, the framework enables on-the-fly access and reuse. Retrieval of relevant components is enabled by automatic decomposition of legacy documents and storage of individual components, enriched with metadata. Furthermore, the automatic assembly of these components in mainstream authoring tools is supported. The paper describes the framework and its current support for re-assembling PowerPoint, Wikipedia and SCORM components in authoring tools. In addition, an evaluation is presented that aims to assess the effectiveness and efficiency of such content reuse for presentations.

1. Introduction

In document engineering, the transformation of documents into forms that ease their reuse is an important research topic (Lecerf & Chidlovskii 2006). The practice of reuse has significant advantages for document creation, maintenance and use. It saves work, improves document quality and increases consistency by eliminating re-doing what has been done before and allowing the user to make a change in one place instead of many (Barta & Gil 1996).

In non-fiction writing, it is a common practice to construct documents from pieces of existing material (Barta & Gil 1996). In the software industry, manuals for a new software release are built from previous versions; in legal writing, adaptation and reuse of previous documents is a universal practice, as lawyers often assemble documents, such as contracts, from existing text templates, filling in a few blanks (Branting & Lester 1996). Also in the pedagogical domain, there is an increasing demand for reusing Learning Objects (Downes 2001, Robson 2004, Duval & Hodgins 2003).

A lot of research has been dedicated to re-assemble document components, often referred to as single sourcing (Ament 2003). Single sourcing implies that there is a single source for content; content is written once, stored in a single source location, and reused many times (Rockley 2002). Recent research focuses on the dynamic re-assembly of content components into personalized documents (Vercoustre & McLean 2005).

However, little work has been done to support automatic decomposition of legacy documents. Instead, guidelines (Schluep 2005) are often provided to decompose content manually or to create new components that are suitable for reuse. The approaches focus on optimizing reuse of content that has been specifically designed for this purpose, however, are unable to scale. If we can decompose documents automatically into reusable components, reuse of numerous document components available on the World Wide Web can be automated.

Automated decomposition is a complex task that does not only involve extracting components. Similarity measures are required to detect reuse and to avoid (near-) duplicates in the repository. A metadata description needs to be automatically added to individual components, taking into account information from the original document to which the component belonged. Support for assembling document components requires tight integration into mainstream authoring tools, as authors prefer to use authoring environments they are familiar with to create content. Finally, there is a need for a ranking mechanism so that searches are only confronted with relevant components and the approach remains scalable.

In earlier work, we have presented an abstract content model (ALOCOM) that is a framework for documents and their components (Verbert et al. 2007, Jovanovic et al. 2005). The model defines content component types at different levels of granularity and relationships between components. As such, the model enables structuring of composite documents and is a solid basis for the proposed automated approach.

In this paper, we present the ALOCOM (de-)composition framework for legacy documents. Decomposition is currently supported for Microsoft PowerPoint presentations, Wikipedia pages and SCORM Content Packages (SCORM 2004). In this process, components are extracted, reuse is detected and metadata is added. Plug-ins have been developed for Microsoft PowerPoint, Microsoft Word and the Reload Editor [4], a packaging tool designed to enable composition of SCORM content packages, that enable authors to search components, such as images, definitions, examples, slides, text fragments, tables or diagrams, from within the authoring tools. Components found in this way are shown in an integrated window and the author can incorporate them directly into the document that is being edited.

We have carried out a user evaluation that assessed the usability of the plug-in for Microsoft PowerPoint. The goals of the evaluation were threefold: (i) to assess the efficiency and effectiveness of the approach for reusing presentations; (ii) to assess the subjective acceptance of the ALOCOM interface; and (iii) to determine to which level of granularity decomposition is relevant. A follow-up evaluation was necessary to confirm the results and assessed the quality of the created presentations.

In the next section, the ALOCOM architecture is presented. Section 3 describes the Microsoft PowerPoint, Microsoft Word and Reload plug-ins that support the aggregation process. User evaluation results are presented in Section 4. The quality evaluation is presented in Section 5, followed by a discussion in Section 6. Related work is described in Section 7. Conclusions and remarks on future work conclude this paper.

2. The ALOCOM Architecture

The ALOCOM architecture facilitates content reuse by decomposing documents into smaller, reusable, components and storing the components individually, enriched with metadata. Furthermore, on-the-fly access to these components is provided. The server relies on the

ARIADNE Knowledge Pool System (Duval et al. 2001) for storage of components and their metadata. The architecture is depicted in Figure 1 and consists of the following components:

1. Client side applications within authoring tools that enable content uploading to and component retrieval from the repository. Plug-ins have been developed that provide these functionalities for Microsoft PowerPoint and Reload. A plug-in for Microsoft Word enables automatic reuse of Wikipedia components in text documents (see Section 3).
2. The Disaggregation module supports the actual decomposition. Presentations are decomposed into slides, and slides are further decomposed into images, tables, diagrams, audio and video sequences, and text fragments. Text documents are decomposed into sections and subsections, and each section is further decomposed into paragraphs, images, tables, diagrams, etc. The current implementation of this module supports the approach for PowerPoint presentations and Wikipedia pages. Components are extracted, preview thumbnails are generated and results are stored through the AdvancedContentInserter (see Section 2.1).

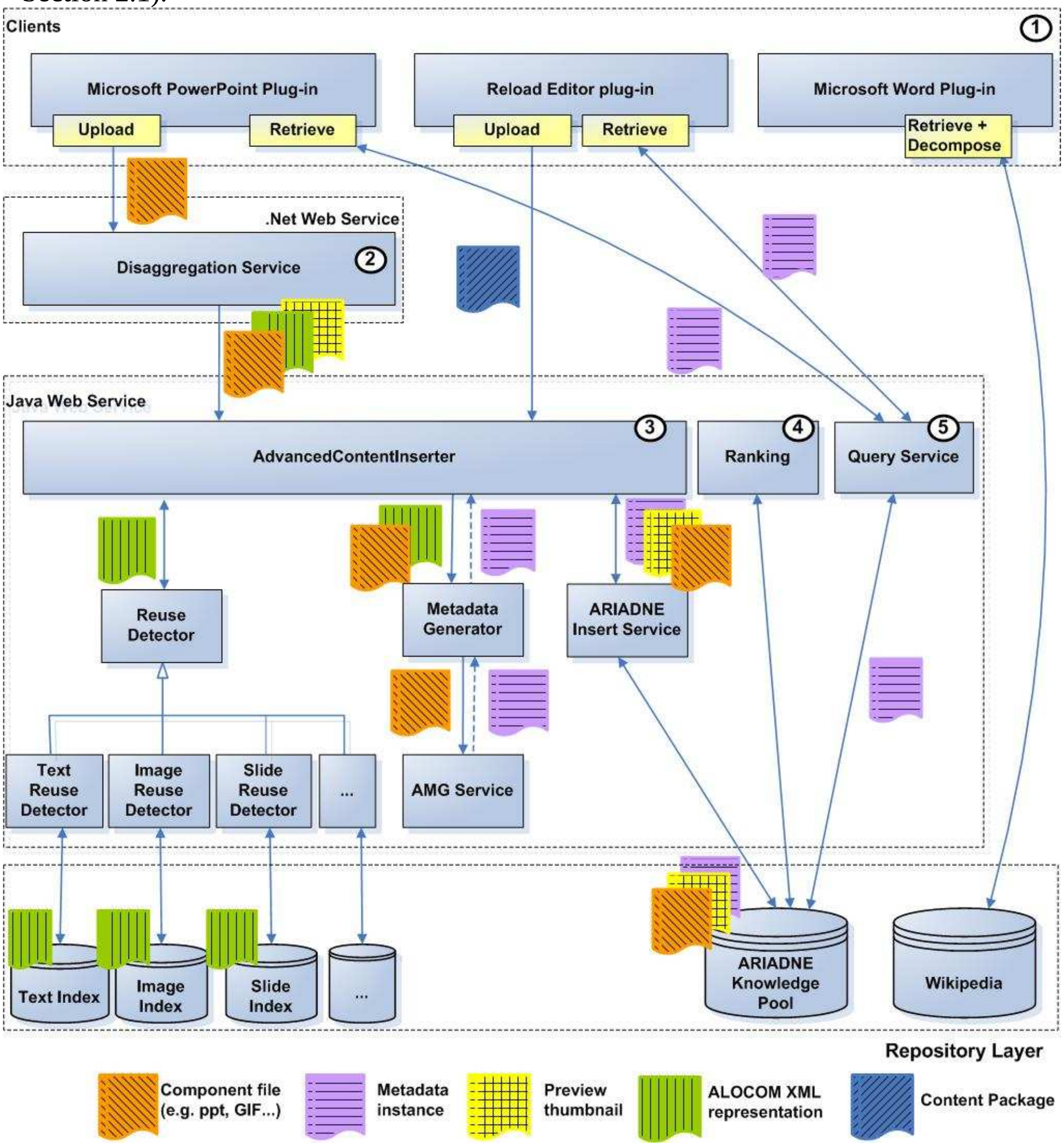


Figure 1: The ALOCOM Architecture

3. The AdvancedContentInserter provides support for storing not only complete documents, but also components that are contained in the document, for instance components stored in a SCORM content package or components that were extracted by the Disaggregation module. The AdvancedContentInserter supports reuse detection for different component types, adds metadata to each component, and stores the components and preview thumbnails in the repository (see Section 2.2).
4. The Ranking module assigns ordering values to components based on their reuse and enables ranking of components in result lists when a user searches for relevant objects, placing components with a high relevancy at the top of the list (see Section 2.3).
5. The Query Service enables retrieval of components. Both descriptive keywords and a component type, such as definition, example, slide, image, diagram or table, can be specified when searching for components. Also advanced queries are supported that enable searching by author, title, main concepts, duration, etc (see Section 2.2.3).

The rest of this section details the server components. The client applications are described in Section 3.

2.1 Disaggregation Module

The disaggregation module automates decomposition of composite documents into components. Granularity is an important factor in this process. The size of a component can vary between a chapter and a single line. The more fine-grained the structure is, the more flexible possibilities for document reuse are obtained. However, more fine-grained also results in a larger set of components and is more complex to manage (Dahn 2001, Rockley 2002). As pointed out by Rockley (2002), sentence fragments or individual words may not be appropriate for reuse. However, single paragraphs may constitute definitions, examples or exercises that are reusable. That is why we decompose to the level of paragraphs. For the approach to remain scalable, modules for detection of reuse, generation of accurate metadata and ranking are incorporated in the framework (see Section 2.2.1, 2.2.2 and 2.3 respectively).

Figure 2 illustrates the decomposition process. Presentations are decomposed into slides, and slides are further decomposed into images, tables, diagrams, animations, audio- and video sequences and text fragments. Text documents are decomposed into sections and subsections, and each section is further decomposed into paragraphs, images, tables, diagrams, etc. The type of information contained in components, such as definition or example, and other relevant information for component retrieval, is determined by the automatic metadata generation module (see Section 2.2.2).

The current implementation of this module automates decomposition of Microsoft PowerPoint presentations and Wikipedia pages. The latter are decomposed on-the-fly at the client side (see Section 3.2). Decomposition of presentations is performed on the server. The module is implemented as a .Net web service and uses the PowerPoint API (Khor & Leonard 2005) to retrieve content and structure from a presentation.

The decomposition method iterates over the slides and slide shapes of a PowerPoint presentation object. Each slide is stored in the PowerPoint format to enable lossless reuse. Images are extracted and stored in their original format and text fragments and tables are stored in an XML format containing their content and structure. For slides, an XML representation is generated to enable their reuse in other applications and for detecting reuse between slides (see Section

2.2.1). Finally, preview thumbnails are generated for each component, using built-in export functions provided by the PowerPoint API. These thumbnails are used in the search interface of client applications (see Section 3.1).

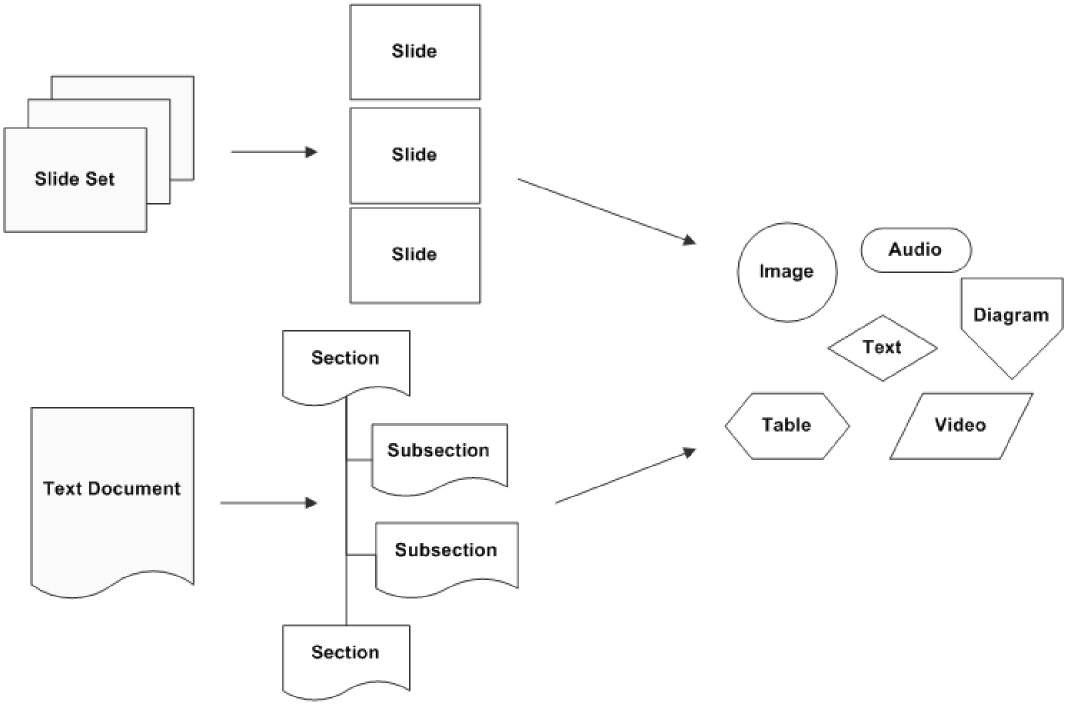


Figure 2: The decomposition process

In the next step, the generated components are sent to the AdvancedContentInserter for storage and indexation.

2.2 AdvancedContentInserter

The AdvancedContentInserter is part of a Java web service that relies on the ARIADNE Knowledge Pool System (Duval et al. 2001) for storage of document components. The module automates reuse detection for individual components and metadata is added by an extended version of the Automatic Metadata Generation (AMG) framework (Cardinaels et al. 2005).

Individual components can be sent to this service, provided with the identifier of the parent component, but also complete packages such as SCORM (SCORM 2004), METS (METS 2007), or MPEG-21 DIDL (Burnett et al. 2005) content packages. Each of them is based on the idea of a central XML manifest file and either references or contains the data files that make up the package. In the latter case, the AdvancedContentInserter processes the manifest file and components are stored individually.

2.2.1 Reuse Detection

Components that are reused in different documents would result in duplicate components in the repository. Reuse detection is used to avoid these duplicates.

Reused components are not always identical copies of the original component. An author can have paraphrased a text component or can have changed some colors in an image. To detect overlaps between text components, techniques can be used that are based on word frequency or sentence occurrences (Shivakumar & Garcia-Molina 1995). These techniques are often used in plagiarism detection tools.

Also for images, techniques exist for detecting near-duplications and for extracting sub-images. In (Yan et al. 2004), a system is presented that detects duplicate images, but also common transformations such as changing contrast, saturation, scaling, cropping, framing, etc. For slides and sections, a combination of text and image reuse detectors can be used. The rest of this section details the techniques used for different component types.

2.2.1.1 Reuse detection for text fragments

Different detection schemes have been proposed for finding text duplicates. In COPS (Brin et al. 1995), documents are broken up into sentences or sequences of sentences, and are stored in a registration server. Subsequent query documents are broken up in the same way and compared against registered documents.

In (Shivakumar & Garcia-Molina 1995), a detection scheme is presented that is based on word occurrence frequencies of text fragments. A similarity measure is used for overlap computation. The authors have evaluated the accuracy of both sentence and word based approaches and report that word chunking performs better as it has the potential to detect finer (e.g., partial sentence) overlap, which may be especially important with documents that may not have a clear sentence structure.

As an accurate overlap computation for often very fine-grained components is a requirement in ALOCOM, the word based comparison scheme is used. Conceptually, a vector is computed that gives the frequency with which each possible word occurs in the text fragment. Then the vector is compared against similar vectors in the repository of registered text fragments.

A Lucene index (Lucene 2007) is used for storing text fragments. New text fragments are compared against text fragments stored in the index. A metric is used to measure the overlap between an incoming text fragment and a pre-registered text fragment. As proposed in (Shivakumar & Garcia-Molina 1995), the cosine similarity measure is used for comparison of two text fragments R and Q:

$$sim(R,Q) = \frac{\sum_{i=1}^{N} \alpha_i^2 * F_i(R) * F_i(Q)}{\sqrt{\sum_{i=1}^{N} \alpha_i^2 * F_i^2(R) * \sum_{i=1}^{N} \alpha_i^2 F_i^2(Q)}}$$

where α_i is the weight associated with the occurrence of the i^{th} word and $F(D)$ (size N) is the *frequency vector*. $F_i(D)$ is the number of occurrences of word w_i in text fragment *D*. Currently, uniform weights for words ($\alpha = 1$) are assumed. Intuitively, the higher the frequency of a word, the less it contributes towards matching similarities (Shivakumar & Garcia-Molina 1995).

To illustrate the similarity computation, consider a registered text fragment R="a b c" and new text fragments S_1="a b c" and S_2="c d e". Using the cosine similarity measure for the example and assuming uniform weights,

$sim(R,S_1) = 1*1+1*1+1*1 \big/ \sqrt{3*3} = 1$ and $sim(R,S_2) = 0*1+0*1+1*1 \big/ \sqrt{3*3} = 0{,}3$.

Identical text fragments have a similarity value 1, while text fragments that do not have much overlap have a low value (e.g. 0,3 in the example).

2.2.1.2 Reuse detection for other component types

For images, a duplicate detection technique has been implemented that uses the MD5 check sum of the file. This technique enables detection of identical images. The idea is to integrate a more advanced copy detection technique in the next step, enabling near-duplicate detection. However, as adaptations to images are much less frequent than adaptations to text fragments, the current technique is working reasonably well. For slides, sections and tables, a combination of text and image reuse detection techniques is used.

2.2.2 Metadata Generation

During decomposition, metadata is added to each component. LOM metadata (Duval 2002) is generated by the Automatic Metadata Generation (AMG) framework (Cardinaels et al. 2005). The idea behind the framework is to combine metadata, generated from different sources, into one metadata instance. The first source is the document itself; the second is the context in which the document is used. Metadata derived from the document is obtained by content analysis, such as keyword extraction and language classification. The contexts typically are content management systems or author institution information.

Additional information gained by the decomposition process is used in the annotation process. For instance, Microsoft PowerPoint provides “place holders” to type the title of a slide. This title is added to the metadata instance as the title of the component.

Furthermore, the metadata describing a component can also be deduced from the metadata for its parents. For instance, each slide in a presentation inherits the author, language, etc. from the presentation to which it belongs. For this purpose, an extension of the framework has been developed that combines metadata by an inheritance mechanism.

Finally, dependency relations between document components are described as relationship metadata. Through additional attributes, we can distinguish different relations between parent and child components (”isPartOf”, ”hasPart”) and between components (”ordering”).

2.2.3 The Query and Insert Service

The ARIADNE query service (Ternier et al. 2003) is used for retrieval of content components and the insert service for inserting components in an ARIADNE Knowledge Pool (Duval et al. 2001). The insert service supports inserting, updating and deleting components and their metadata.

The ALOCOM repository is currently filled with 62841 components that were extracted from 814 documents. These components include 18149 slides, 7028 images, 226 tables, 30 diagrams and 35460 text fragments.

2.3 Ranking

Document decomposition results in a repository filled with numerous components. Hence, there is a need for a ranking mechanism so that searches are only confronted with relevant components and the approach remains scalable. The ranking function assigns a value to a component based on three metrics:

- the number of times that the component has been reused directly,
- the number of times that the component has been reused as part of a bigger component,
- and the number of different authors that have reused the component.

While these metrics measure the historical probability that a component will be reused, a more useful approach is to calculate the probability that a component will be selected on a specific date. This probability is calculated providing a time frame, for example the previous month or year, where reuse will be measured. The rationale for this strategy is that successful components are often updated with new, improved versions, for example yearly time series charts with information for a new year. To avoid recommendation of old and potentially deprecated components, only fresh reuse information is used. Old components that are still actively reused are not affected by this time-based bias.

The implementation is based on the ideas of Learning Object popularity ranking explained in (Ochoa & Duval 2006). Reuse information is converted into a graph structure where components are linked to components that include them. For example, a table is linked to the slides that contain it. If the component does not have a higher container, it is linked to the users that created or reused the component. The edges of this graph are annotated with the date the reuse took place. The edges are then pruned according to the desired time-frame and the resulting graph is used to calculate the different reuse metrics explained above, based on the incoming edges of a component and the links between components and users.

The metrics are calculated a priori because they are not user or query specific. Results are stored in the repository and are used to rank result lists of components when a user searches for relevant objects, placing components with a high probability at the top of the list. Evaluation results are presented in Section 4.

3. Client Side Applications

Client side applications were developed that enable content upload and component retrieval from within authoring tools. Such applications were developed for Microsoft PowerPoint, Microsoft Word and the Reload Editor. The plug-ins are detailed in the rest of this section.

3.1 Microsoft PowerPoint Plug-in

A plug-in has been developed for Microsoft PowerPoint that enables authors to reuse components stored in the ALOCOM repository from within the application. As shown in Figure 3, a custom Office Task Pane (on the right side) is used for integrating this functionality. This is accomplished with Visual Studio 2005 Tools for the Microsoft Office System [7].

The plug-in enables authors to search the repository for components they wish to reuse in the presentation they are editing. An author can specify both the component type, such as reference, definition, example, slide, image, or text fragment, and descriptive keywords. Thumbnails of components that satisfy the search criteria are displayed in the ALOCOM Task Pane and metadata associated with a component is shown if the user hovers the mouse pointer over a component in the result list.

The author can incorporate a component into the current presentation by a single mouse-click. The original component is then retrieved and automatically added using built-in copy and paste functions of the PowerPoint API. Doing so, all original content, structure and layout information, including transitions in a slide, is preserved.

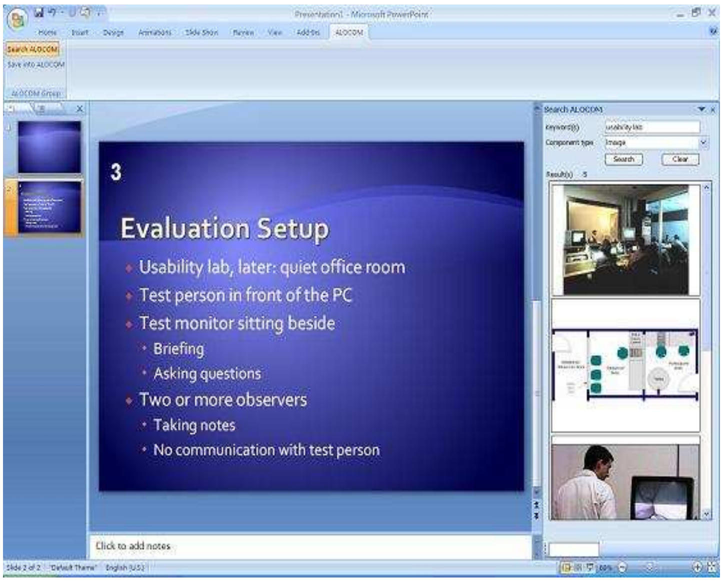


Figure 3: The ALOCOM plug-in for Microsoft PowerPoint [1]

In the opposite direction, authors can add presentations to the repository by clicking the “Save into ALOCOM” button that has been added to the standard PowerPoint menu. When this button is clicked, the presentation is sent to the .Net disaggregation service for decomposition and storage.

3.2 Microsoft Word Plug-in

A similar plug-in has been developed for Microsoft Word that automates reuse of Wikipedia components. All definitions, images, references, and text fragments can be individually retrieved. In fact, Wikipedia pages are easy to disaggregate, as the pages have a consistent structure and are stored in well-formed HTML. The first part of the page provides a general definition of the concept. Further content is divided into smaller, clearly labeled, sections.

In contrast to decomposition of presentations, which takes place when they are stored in the ALOCOM server, decomposition of Wikipedia pages is performed upon request at the client side. The Wikipedia search engine is used for retrieval of relevant pages. An HTML parser processes found pages and retrieves their content and structure. The first part of the page is retrieved when searching for a definition. Other sections are retrieved when searching for text fragments, disaggregated to the level of single paragraphs, labeled with the title of the subsection to which they belong. Images on Wikipedia have in most cases “alt” attributes that provide a short description. Finally, references are retrieved by parsing the “reference” section in a page.

Similar to the Microsoft PowerPoint plug-in, a custom task pane is defined that enables retrieval of Wikipedia components from within the authoring tool (see Figure 4). A user can specify both keywords and the component type. When searching for text fragments, paragraphs are shown individually, with their surrounding paragraphs. Also the complete section to which the paragraph belongs is retrievable. This support is required, as not many paragraphs are written as standalone pieces of content and often refer to other paragraphs. By showing the surrounding paragraphs, an author is provided with sufficient context to understand the content and chooses whether a paragraph can be reused as a standalone component or should be reused in combination with other paragraphs.

3.3 Reload Editor Plug-in

The key aim of the Reload project is the implementation of a SCORM Content Package and Metadata Editor. The Reload Editor enables users to organize, aggregate and package Learning Objects in SCORM content packages tagged with metadata [4].

A SCORM content package is a self-contained ZIP file. Mandatory Content Package contents are an XML manifest file (imsmanifest.xml), schema definition files referenced by the manifest file and all component files used by the content package.

The manifest file describes the structure and contents of the package. The Reload Editor allows authors to create and edit such manifest file with a convenient graphical interface to visualize the content. A plug-in has been developed for this editor that enables retrieval of components stored in the ALOCOM repository (see Figure 4). A user can enter descriptive keywords and a component type and results are shown in an integrated window. Components in the result list can be dragged and dropped into a specific location in the manifest file. When a component is added, the original component file is retrieved and stored on the client machine. Metadata associated with the component is automatically added to the manifest file.

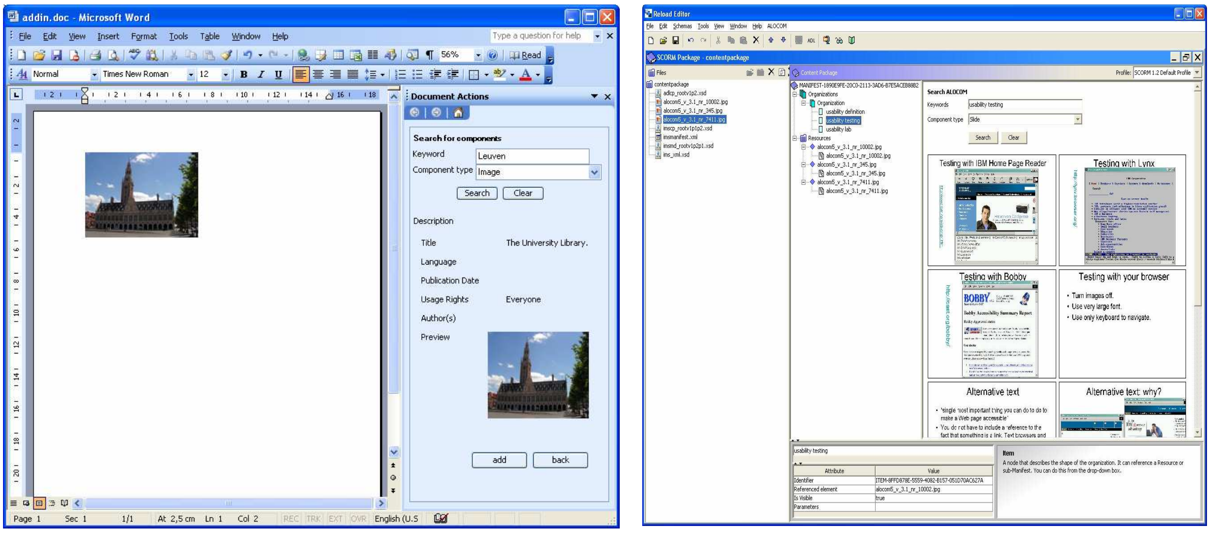


Figure 4: The ALOCOM plug-in for MS Word (left) and the Reload Editor (right)

In the opposite direction, support for decomposing SCORM content packages is provided. This decomposition process is straightforward as components in the content package are already stored individually and described by metadata. The AdvancedContentInserter unpacks the package and stores the components in the repository. Metadata is generated by the AMG framework and merged with metadata that the author might have provided in the manifest file.

4. User Evaluation

The user evaluation assessed the usability and utility of the ALOCOM plug-in for Microsoft PowerPoint. The goals of the evaluation were the following:

- to assess the efficiency and effectiveness of the approach for reusing presentation components;
- to assess the subjective acceptance of the ALOCOM interface;

- to determine to which level of granularity decomposing presentations is relevant;
- to assess the efficiency and effectiveness of the ranking algorithm.

4.1 Study Description

The study was conducted in October 2006 at the K.U. Leuven University. Each session involved one participant, who performed two tasks during a single session. There were 20 participants in the study, which typically results in a reasonably tight confidence interval (Nielsen 2006). Participants were mainly members of the junior staff of the Computer Science Department at K.U. Leuven.

4.1.1 Tasks

Each participant was asked to create two presentations: one on inheritance and one on exceptions in the programming language Java. The participants were divided in two groups. The first group created the presentation on exceptions in Java without ALOCOM support, and the presentation on inheritance in Java with ALOCOM support. They could use all information available on the World Wide Web for both presentations. The second group did the same, but in a different order. This group created the presentation on inheritance in Java without ALOCOM support, and the presentation on exceptions in Java with ALOCOM support.

The presentation created without ALOCOM support is referred to as *without-alocom presentation* and the presentation created with ALOCOM support as *with-alocom presentation* in the remainder of this paper.

In order to bootstrap the reuse process, 78 presentations on both topics were gathered by a Google search and uploaded to the repository: as described above, they were automatically decomposed and the components were automatically described. In total, 10281 components were made available for reuse, including 2964 slides, 933 images, 6367 text fragments, 12 tables and 5 diagrams.

4.1.2 Data Collection

Camtasia Studio [2] was used to record participant interactions, capturing the screen, voice and webcam video. Participants were also asked to complete a questionnaire after the tasks. The questionnaire was adopted from a usability evaluation of the ARIADNE search tool (Najjar et al. 2005). Rank positions of selected components were logged in Contextualized Attention Metadata (CAM) files (Wolpers et al. 2007).

4.1.3 Measurements

The following characteristics were measured for the experiment:

- Time-on-task: represents the time needed to finish each task. The aim is to investigate whether the use of the ALOCOM plug-in can lead to savings in time. Time is influenced by other factors; however, this comparison is included in order to obtain a first indication of improvements for time-on-task.
- Manual versus semi-automatic reuse: the distinction is made between manually reused components and semi-automatically reused components. Manually reused components are components that were added to the presentation by copy-pasting or reproducing existing

content, typically found through Google. Semi-automatically reused components are those components that were found and inserted using the ALOCOM plug-in. By measuring and comparing both types of content reuse, a success rate indication of the ALOCOM approach for reusing content is obtained, as authors typically tried the semi-automatic approach first and inserted content manually if no relevant components were found through the ALOCOM plug-in.

- Component granularity: the granularity of semi-automatically reused component types is measured in order to determine to which level of granularity decomposition of presentations is relevant.
- Satisfaction: user satisfaction was assessed through a questionnaire filled in by each participant after finishing the tasks.

4.2 Results

4.2.1 Time

Table 1 shows the average time participants spent on creating *without-alocom* and *with-alocom* presentations. At first sight, the difference is relatively limited: on average, 20.03 minutes were spent creating the *without-alocom* presentation and 17.79 minutes creating the *with-alocom* presentation. However, not all participants created presentations similar in length, covered sub-topics or quality in general.

Size normalizations were applied that were adopted from the software quality field (ISO/IEC 9126 1998). A simple normalization that takes into account the number of slides in the presentation shows that on average 3.32 minutes were spent per slide in a *without-alocom* presentation, whereas 2.2 minutes were spent per slide created with ALOCOM support.

A second normalization was applied that takes into account the number of sub-topics. Some participants created presentations covering many sub-topics, such as polymorphism and dynamic binding for the presentation on inheritance, while others provided only a definition and an example. On average 4.5 minutes were spent on a sub-topic in a *without-alocom* presentation and 2.9 minutes on a *with-alocom* presentation sub-topic.

Table 1. Time (in minutes)

	without-alocom presentation	with-alocom	Sig.(2-tailed)
Total time	20.03	17.79	0.147
Time normalized by number of slides	3.32	2.2	0.001
Time normalized by number of subtopics	4.5	2.9	0.016

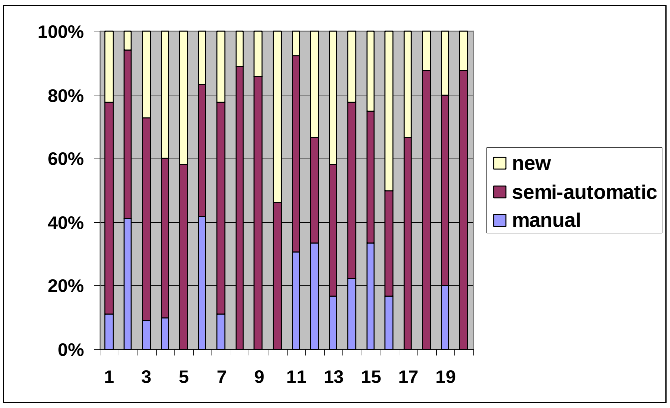
To statistically establish whether the difference between these average values is real or a by-product of natural variance, we applied a Paired-Samples T Test. The null hypothesis is that there is no difference between the required creation time for *with-alocom* and *without-alocom* presentations. Our alternative hypothesis is that there is indeed a difference. Results were normally distributed. Normality was tested with the Kolmogorov-Smirnov test (Massey 1951).

The null hypothesis can be rejected for normalized time values. Thus, taking into account the size of presentations, significant time savings are realized when creating presentations with support to automatically reuse existing presentation components. To validate these results, a second evaluation was performed that assessed the quality of the created presentations. This evaluation is presented in section 5.

4.2.2 Reuse in With-Alocom Presentations

With-alocom presentations were further analyzed. The distinction is made between manual reuse, semi-automatic reuse and new components. Manually reused components are components that were added to the presentation by copy-pasting or reproducing existing content, found by a web search. Semi-automatically reused components are those components that were found and inserted using the ALOCOM plug-in. New components represent content the participant created from scratch, without using an existing resource.

Figure 5 (left) shows reuse patterns of individual participants. Some participants reused about the same amount of components manually than semi-automatically. Also, the amount of new components is high for some participants (more than 40%). Few participants created presentations without manual reuse.



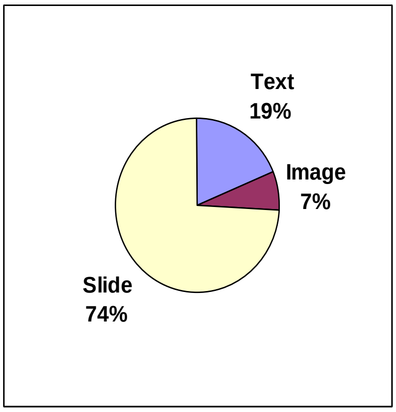


Figure 5: Reuse patterns of individual participants (left); reuse/component type (right)

Table 2 shows that on average 57% of presentation components are semi-automatically reused using the ALOCOM plug-in. 18% of the components were reused manually, whereas 25% are new components. There is no significant difference if we compare this data for the presentation on exceptions in Java and the presentation on inheritance in Java, although more components were available covering topics on inheritance. The values were normally distributed and compared with a Paired-Samples T Test.

Table 2. Reuse in *with-alocom* presentations

	Manual	Semi-automatic	New
Overall	0.18	0.57	0.25
Presentation on inheritance (1)	0.19	0.58	0.23
Presentation on exceptions (2)	0.18	0.55	0.27
Comparing means (1) and (2) Sig. (2-tailed)	0.737	0.121	0.791

Comparing manual and semi-automatic reuse, we see that 76% of reused components were reused semi-automatically, whereas 24% were reused by copy-paste actions or reproduction of content. These values are a success rate indicator of the ALOCOM approach for reusing content, as participants typically tried the semi-automatic approach first and inserted content manually if no relevant components were found through the ALOCOM plug-in.

4.2.3 Granularity

Figure 5 (right) shows the reuse rate for semi-automatically reused component types. Complete slides are most often reused, probably because many slides represent a single idea or topic and are thus easy to reuse in a new context. Also the reuse of text fragments is significant. This is an interesting result, as it illustrates that breaking content down to the level of a single text fragment is useful. Images were not frequently reused; however, this result is probably influenced by the topic of the presentations.

4.2.4 Effectiveness of the Ranking Algorithm

26% of selected components were presented in the top position, 77% in the top 5 and 87% in the top 10 (see Figure 6). This result is consistent with previous findings (Ochoa 2007) that indicate that reuse popularity of a document is highly correlated with its relevance for a closely related group of users (in this case computer scientists from the same department) performing a similar task (creating a presentation on a similar topic). Also interesting, a non-negligible amount of components (10%) were retrieved from positions between 15 and 52. This result goes against the accepted belief that users select only results in top positions. This can be explained as the experimental setup interfering with the normal behavior of users.

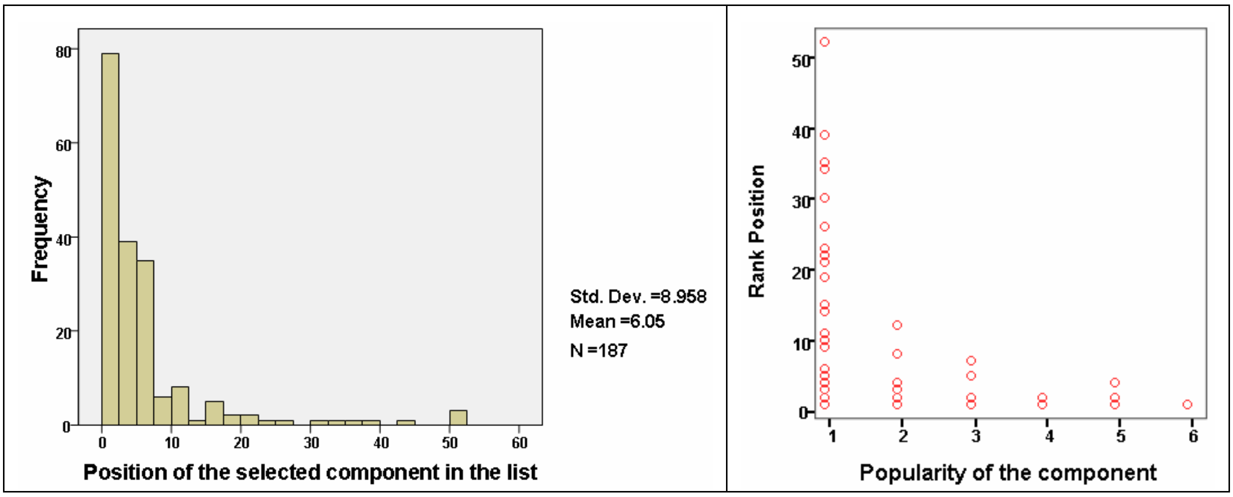


Figure 6: Effectiveness of the ranking (left) rank versus popularity (right)

The relevance of popular components is also reflected in the number of times that content components were reused in the experiment. The most reused components tend to appear in the first positions in the ranking. As shown in Figure 6 (right), the rank position of the most popular objects (6, 5 or 4 reuses) is inside the top 5. This result implies that it is possible to feed the ranking algorithm with the popularity values captured during the experiment without affecting the stability of the ranking positions in a major degree. Such behavior is very desirable for a ranking algorithm.

4.2.5 Findings and Recommendation.

In this section, findings and recommendations of the participants are discussed.

4.2.5.1 Lack of Context

Some participants remarked that more context is required for successful content reuse. They want to be able to retrieve the next and previous slide for a specific slide in the result list, or even the complete presentation(s) to which the slide belonged. Similar support is needed for other component types.

4.2.5.2 Behaviour Change

It was noted that this way of reusing content requires a behaviour change, as it is different from the usual practice of copy-pasting or reproducing content. It was reported that savings in time would be remarkable; however, a period of adaptation is required.

4.2.5.3 Drag and Drop Support

Many participants expected drag and drop support for inserting components. There is click-support for inserting a component: clicking a component in the result list will insert the component at the currently selected location. However, it is not possible to drag the component to a different location in the presentation due to limitations of the PowerPoint API.

4.2.5.4 Garbage Content

Not all components are reusable. As components are created by decomposing existing content automatically, it was expected that not all components are valuable for reuse. Results are ranked according to the number of times a component is reused. Hence, the impact of this issue will decrease over time.

4.2.5.5 Less Consistent Layout

Some participants noted that it is hard to keep the layout of different components consistent. The layout of slides is automatically adapted to the template the author is using. However, if the author changed for instance the font color of a text fragment in one particular slide, this modification is preserved when reusing the slide. Although desirable in some cases, this was reported as a difficulty.

4.2.5.6 More Valuable for Reuse of Own Content

Participants remarked that the use of the ALOCOM plug-in would be most valuable for reusing their own presentations.

4.2.6 Overall Satisfaction.

Table 3 presents the responses of participants to questions concerning the overall use of the ALOCOM plug-in. The questionnaire was adopted from a usability evaluation of the ARIADNE search tool (Najjar et al. 2005). The popular attitude scale with seven points (ranging from 1 - poor to 7 - good) was used to measure the response of participants on the overall use of the plug-in.

Table 3. Satisfaction

	mean (ranging from 1–7)	Standard deviation
Ease of use	6.15	0.69
Information organization	5.23	0.93
Use of terminology	4.92	1.5
Navigation	6.07	1.04
Search and reuse of components	5.69	1.49
Result list easy to read	4.92	1.5

The mean for the level of ease-of-use was more than 6, meaning that the participants found the ALOCOM plug-in easy to use. The level of information organization and search and reuse of content components was perceived as moderate (mean 5.23 and 5.69 respectively). We believe that this is related to the fact that there is a lack of context (it is not possible to automatically retrieve the original component to which a component belonged) and the fact that there is no drag and drop support.

Result lists were found rather difficult to read (mean 4.92). This result is a consequence of the fact that preview thumbnails of slides containing much content are difficult to read. We have worked on a solution that enables users to enlarge individual components. Each component in the result list has a context menu item that provides this functionality. This solution will resolve the issue if only few components are difficult to read.

5. Quality Evaluation

In a follow-up evaluation, the quality of *with-alocom* and *without-alocom* presentations was assessed by a group of 19 participants. This evaluation was necessary for obtaining a more accurate estimation of the effectiveness and efficiency of the ALOCOM approach for reusing presentations.

Following a common practice to reduce subjectivity in a quality evaluation, an evaluation framework was used. In (Knight & Burn 2005), an overview is provided of the most common dimensions of Content Quality frameworks. Four dimensions that were relevant in the context of the experiment were used to evaluate the quality of the presentations: accuracy, completeness, relevancy and conciseness.

In an accurate presentation, the content contained in the presentation is correct, reliable and free of error. Completeness is defined as the extent to which information is not missing and is of sufficient breadth and depth for the task at hand. Relevancy measures whether the content contained in the presentation is applicable and helpful for the task at hand. Finally, in a concise presentation, content is broken up into smaller chunks that can be easily shared with an audience.

Participants in the experiment were requested to read the definition of each parameter before grading the presentations. The definitions were also available during the evaluation process.

The experiment was carried out online using a web application. After logging in, the system presented users with instructions. After reading the instructions, users were presented with a list of 20 randomly selected presentations. Once users had reviewed a presentation, they were asked to give grades on a 7-point scale, from "Extremely low quality" to "Extremely high quality", for each parameter. Only participants that graded all presentations were considered in the experiment.

The experiment was available for 2 weeks. During that period, 24 participants entered the system, but only 19 completed the evaluation. From those 19 participants, 13 were postgraduate students, 1 had a Ph.D. degree and 5 were active in software development. All participants had a degree in computer science.

5.1 Data Analysis

Because of the inherent subjectivity in measuring quality, the first step in the analysis of the data is to estimate the reliability of the evaluation. In this kind of experiment, the evaluation is considered reliable if the variability between the grades given by different reviewers to a particular presentation is significantly smaller than the variability between the average grades given to different presentations. To estimate this difference, we used the Intra-Class Correlation (ICC) coefficient (Shrout and Fleiss 1979), which is commonly used to measure the inter-rater reliability. We calculated the average ICC measure using the two-way mixed model, given that all reviewers grade the same sample of presentations. In this configuration, the ICC is equivalent to another widely used reliability measure, the Cronbachs alpha (Cronbach 1951). The results for each quality parameter are reported in the Table 4.

Table 4. Intra-Class Correlation (ICC) coefficient for measuring the reliability

Parameter	ICC (average, two-way mixed)
Completeness	0.927
Accuracy	0.766
Conciseness	0.881
Relevancy	0.837

Generally, ICC values above 0.75 indicate good reliability between measures. None of the values fall below this cut-off value. Hence, the ICC suggest that reviewers provided similar values and further statistical analysis can be performed.

The second step is to assess whether there is a difference between the average grade given to *with-alocom* presentations and the average grade given to *without-alocom* presentations. These average values are presented in Figure 7. To statistically establish whether the difference between average values is real or a by-product of the natural variance, we applied a Paired-Samples T Test. Our null hypothesis is that there is no difference between the grades given to *with-alocom* and *without-alocom* presentations. Our alternative hypothesis is that there is indeed a difference. The results are presented in Table 5. Results were normally distributed.

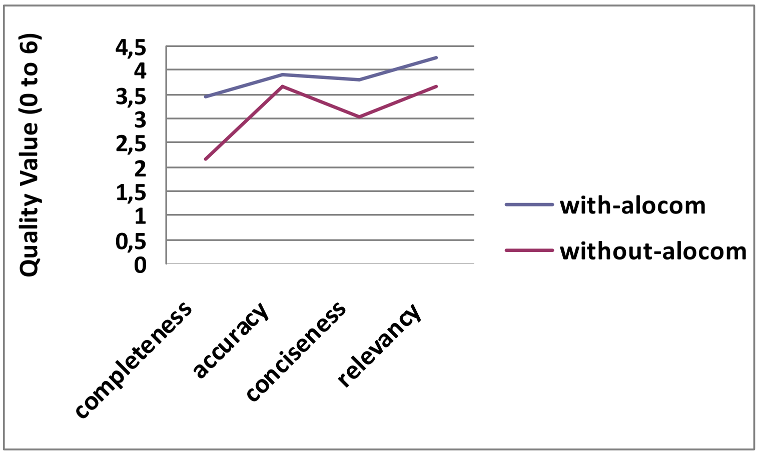


Figure 7: Average quality grade for the different parameters

Table 5. Significance of the difference between the given grades

Parameter	T-value	Significance (2-tailed)
Completeness	-8.094	0.0
Accuracy	-1.412	0.160
Conciseness	-4.352	0.0
Relevancy	-2.981	0.003

The null hypothesis can be rejected for most of the parameters (completeness, conciseness and relevancy). The significant difference found in the completeness parameter indicates that users were able to create more complete presentations when provided with support to reuse presentation components. The significant difference found in the conciseness parameter indicates that content extracted from existing presentations is more suitable for reuse as it is already presented in a form that can be shared with an audience. Furthermore, users were able to find more relevant content for *with-alocom* presentations. No significant difference was found in the accuracy parameter. As the presentations were created by members of the junior staff of the Computer Science Department at K.U. Leuven, it was expected that no major mistakes would be made in creating presentations on inheritance and exceptions in Java.

6. Discussion

Although no direct saving in time was perceived, results of the quality evaluation indicate that providing on-the-fly access to presentation components in an authoring process enhances the quality of presentations. Presentations created with ALOCOM support are significantly more complete, concise and relevant. The results in completeness are consistent with the size normalizations applied to time values. Hence, there is also a significant improvement in time savings.

Results of the user evaluation indicate that the plug-in can be used in a successful way: 76% of reused components were reused semi-automatically. However, usability issues need to be resolved in order to make this kind of content reuse more efficient. Most important is the context issue. The user interface should be extended with the functionality to retrieve the component to which a component in the result list originally belonged. Furthermore, it is important to enable navigation in the original structure of presentations. For instance, support is needed to retrieve the next and previous slide for a specific slide in the result list. These functionalities will be integrated in the PowerPoint plug-in.

The consistent layout issue cannot be improved, as built-in copy and paste functions of the PowerPoint API are used for adding an existent slide to a presentation. If a user would manually copy-paste a slide, the same problem with consistency arises. Drag and drop support is also difficult to integrate. However, possibilities will be investigated to improve the way a component can be inserted.

The method used can be classified as a "discount usability engineering" approach (Nielsen 1989) as it is definitely not "the perfect" method for evaluation and will not give absolute results. However, it enabled us to obtain a good indication of improvements towards savings in time or enhancements of quality and to highlight usability issues.

The evaluation of the ranking algorithm indicates that ranking based on aggregation relationships provides an easy and effective way to rank the results when the components in the repository are covering similar topics. Nonetheless, a small, but not non-neglectable, amount of components were not ranked according to their relevance to the users in the experiment. These errors could be solved when more usage data is fed into the popularity ranking algorithm or using more advanced techniques, for instance personalized or contextual relevance ranking (Ochoa & Duval 2007), during the ranking calculation.

To enable such mechanism, the Contextualized Attention Metadata (CAM) framework (Wolpers et al. 2007) can be used for capturing the attention a user spends on content. ALOCOM client applications already generate such streams that capture activities within the application with timestamp and content-related data. For instance, the time a user spends working on a document, the queries that are performed and the components that are reused by the user, are captured. In the next step, this data will be used for building user attention profiles that represent actual interests of users based on documents they worked with. The use of such profiles enables personalized ranking.

7. Related Work

In recent years, a lot of research has been dedicated to develop flexible documents that are generated by assembling smaller, reusable, components. However, few approaches support automatic decomposition of existing documents. Instead, guidelines are often provided to decompose content manually or to create new components suitable for reuse. Such guidelines are for instance described in the dLCMS project (Schluep 2005). Some commercial content management systems, such as Vasont [6], also use a manual transformation process to support content reuse. The approach presented in this paper is more scalable as it attempts to automate content reuse for pre-existing documents.

MagIR (Kienreich et al. 2005) is a system that supports automatic content transformations. Like in ALOCOM, these transformations are supported for PowerPoint presentations and include content decomposition. Decomposition is supported to the level of slides only, while ALOCOM also extracts smaller components, such as tables, diagrams, images and text fragments. Results of the user evaluation presented in this paper indicate that these fine-grained components are also often reused. MagIR is used for creation, administration and reutilization of PowerPoint slides in a corporate context and is aimed at reducing storage costs. The system has been evaluated in that context and results indicate that storage costs are significantly reduced.

Slide executive [5] is a commercial product that also supports reutilization of Microsoft PowerPoint slides. Individual slides can be retrieved in a browser and dragged and dropped in a PowerPoint presentation. Like MagIR, decomposition is supported to the level of slides. Add-ins are provided to export PowerPoint slides to images in different formats and to import multiple images at once. However, no tight integration for component searching from within the application is supported. No information has been found whether the system has been evaluated.

The TRIAL-SOLUTION project is developing tools to create and deliver personalized teaching materials that are composed from a library of existing documents on mathematics at undergraduate level (Lenski & Wette-Roch 2001). The focus of the project is on document (de-)composition and exchange for reuse. The TRIAL-SOLUTION System contains a splitter that decomposes document source files into a hierarchy of slices. For this decomposition, the presentation style of a particular author is taken into account. Also, it takes care of counters and key phrases assigned by the author. In addition, decomposed content is manually revised. The main difference is that the methodology for decomposing content is semi-automatic and therefore less scalable.

The Legacy Document Conversion (*LegDoC*) project is offering advanced techniques to automate conversion of legacy documents to XML (Lecerf & Chidlovskii 2006). Layout-oriented formats like PDF, PS and HTML are automatically converted to semantic-oriented annotations. The table of contents of a document is used as a basis for document structuring. The approach is promising as no assumptions are made about the structure of source documents. Integrating such approach into the ALOCOM framework would enable structuring and decomposition of unstructured or semi-structured documents that contain a table of contents.

8. Conclusions

In this paper, a framework has been presented that enables scalable content reuse by decomposing presentations, Wikipedia pages and SCORM content packages into reusable components and supporting their on-the-fly reuse in mainstream authoring tools. The analysis of the results of the user and quality evaluations of the approach for presentations indicates that there is a significant improvement of the quality of presentations and a significant time saving benefit.

The successful application of the approach largely depends on the performance of all its components. An accurate reuse detection mechanism is required for avoiding duplicates, components need to be precisely described to enable their retrieval and a ranking mechanism is a key requirement when dealing with a large number of components. In the next steps, a personalized ranking mechanism will be integrated that is expected to further improve the efficiency of the approach. Techniques for transforming unstructured or semi-structured documents need to be investigated to enable component reuse for a wider variety of documents. Finally, evaluations of the MS Word and Reload plug-ins are required to assess their impact on effective and efficient content reuse.

Acknowledgements

We gratefully acknowledge the financial support of the K.U.Leuven research council through the BALO project, the Interdisciplinary Institute for Broadband Technology (IBBT) through the Acknowledge project, and the European Commission through the ProLearn Network of Excellence on Professional Learning [3].

References

Ament, K. (2003) Single Sourcing: Building Modular Documentation. (Norwich NY: William Andrew Publishing)

Barta, D., and Gil, J. (1996), "A system for document reuse". In *Proceedings of the 7th Israeli Conference on Computer systems and Software Engineering*, edited by Beeri, C., Winokur, M. and Levi, S. (Washington, DC, USA: IEEE Computer Society Press), pp. 83–94 http://ieeexplore.ieee.org/iel3/4098/12044/00554856.pdf?tp=&isnumber=&arnumber=554856

Branting, L. and Lester, J. C. (1996), "Justification structures for document reuse". In *Proceedings of the Third European Workshop on Case-Based Reasoning (EWCR-96)*, edited by Ian F. C. Smith, and Boi Faltings (London, UK: Springer-Verslag), pp. 76-90 http://citeseer.ist.psu.edu/branting96justification.html

Brin, S., Davis, J. and Garcia-Molina, H. (1995). "Copy detection mechanisms for digital documents." In *Proceedings of the 1995 ACM SIGMOD international conference on Management of data*, edited by Carey, M. and Schneider, D. (New York, NY, USA: ACM press), pp. 398 - 409 http://citeseer.ist.psu.edu/brin95copy.html

Burnett, I.S, Davis, S.J. and Drurry, G. M. (2005). MPEG-21 Digital Item Declaration and Identification—Principles and Compression. IEEE Transactions on Multimedia, Vol. 7, No. 3, June 2005 http://ieeexplore.ieee.org/iel5/6046/30857/01430715.pdf

Cardinaels, K., Meire, M., and Duval, E. (2005), "Automating Metadata Generation: the Simple Indexing Interface", *In Proceedings of the 14th International World Wide Web Conference*, edited by Ellis, A. and Hagina, T. (New York, NY, USA: ACM press), pp. 548-556 http://www2005.org/cdrom/docs/p548.pdf

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika, Vol. 16, No. 3, 297-334

Dahn, I., Armbruster, M., Furbach, U., and Schwabe, G. (2001). Slicing Books – The Authors' Perspective, in *Writing Hypertext and Learning: Conceptual and Empirical Approaches*, edited by Bromme, R. and Stahl, E. (New York, Oxford: Pergamon Press) http://www.uni-koblenz.de/~dahn/articles/Slicing-Bromme.pdf

Downes, Stephen (2001), "Learning Objects: resources for distance education worldwide", in *International Review of Research in Open and Distance Learning*, Vol.2, No. 1 http://www.irrodl.org/index.php/irrodl/article/viewFile/32/81

Duval, E., Forte, E., Cardinaels, K., Verhoeven, B., Van Durm, R., Hendrikx, K., Wentland-Forte, M., Ebel, N., Macowicz, M., Warkentyne, K. and Haenni, F. (2001) "The ARIADNE Knowledge Pool System", in *Communications of the ACM,* Vol. 44, No. 5, 72-78 http://portal.acm.org/citation.cfm?id=374308.374346&coll=GUIDE&dl=GUIDE&CFID=400103&CFTOKEN=14494780

Duval, E. (2002), editor. 1484.12.1 IEEE Standard for learning Object Metadata. June 2002. http://ltsc.ieee.org/wg12

Duval, E. and Hodgins, W. (2003). "A LOM research agenda," *In Proceedings of the 12th International World Wide Web Conference*, edited by Hencsey, G. and White, B. and Chen, Y. and Kovacs, L. and Lawrence, S. (New York, NY, USA: ACM press) , pp. 1-9 http://www2003.org/cdrom/papers/alternate/P659/p659-duval.html.html

ISO/IEC 9126 -2 (1998) Software quality characteristics and metrics - External metrics

Jovanović, J., Gašević, D., Verbert, K., and Duval E. (2005). "Ontology of learning object content structure". *In Proceedings of the 12th International Conference on Artificial Intelligence in Education*, edited by Looi, C.-K. and McCalla, G. and Bredeweg, B. and Breuker, J. (Amsterdam: IOS press), pp. 322-329. http://ariadne.cs.kuleuven.be/alocom/papers/AIED-submission.doc

Khor, S.-M., and Leonard, Art (2005). "Installing and Using the Office 2003 Primary Interop Assemblies", Microsoft Office 2003 Technical Articles. Retrieved July 30, 2007, from http://msdn2.microsoft.com/en-us/library/aa159923(office.11).aspx

Kienreich, W., Sabol, V., Ley, T., Lindstaedt, S., Koronakis, P. and Droschl, G. (2005)," MagIR: Distributed Creation, Administration and Reutilization of Multimedia Presentation Content", In *Proceedings of WM 2005: Professional Knowledge Management - Experiences and Visions, Contributions to the 3rd Conference Professional Knowledge Management - Experiences and Visions,* edited by Althoff, K.-D., Dengel, A., Bergmann, R., Nick M. and Roth-Berghofer, T. (Kaiserslautern: DFKI), pp. 481-486.

Knight, S.A. and Burn, J.M. (2005) "Developing a Framework for Assessing Information Quality on the World Wide Web", Informing Science Journal, Vol. 8, pp. 159-172 http://inform.nu/Articles/Vol8/v8p159-172Knig.pdf

Lecerf, L. and Chidlovskii, B. (2006). "Document annotation by active learning techniques." In *Proceedings of the 2006 ACM Symposium on Document Engineering*, edited by Dick C. A. Bulterman, and David F. Brailsford (New York, NY, USA: ACM press), pp. 125-127 http://portal.acm.org/citation.cfm?id=1166194

Lenski, W. and Wette-Roch, E. (2001). "The TRIAL-SOLUTION Approach to Document Re-use Principles and Realization". In *Proceedings of Electronic Media in Mathematics*, 2001.

Lucene. (2007). The Apache Lucene Project: Open-source Search Software, Retrieved June 23, 2007, from http://lucene.apache.org/java/docs

Massey, F.J. (1951), "The Kolmogorov-Smirnov Test for Goodness of Fit", Journal of the American Statistical Association, Vol. 46, No. 253, 68-78

METS. (2007). Metadata Encoding and Transmission Standard. Retrieved June 23, 2007, from http://www.loc.gov/standards/mets/mets-home.html

Najjar, J., Klerkx, J., Vuorikari, R. and Duval, E. (2005), "Finding Appropriate Learning Objects: An Empirical Evaluation", In *Proceeding of the 9th European Conference on Research and Advanced Technology for Digital Libraries*, edited by Rauber, A., Christodoulakis, S. and Min Tjoa, A. (Springer), pp. 323-335 http://www.cs.kuleuven.ac.be/~najjar/papers/ECDL2005.pdf

Nielsen, J. (1989). Usability engineering at a discount. In *Designing and Using Human-Computer Interfaces and Knowledge Based Systems*, edited by Salvendy, G., and Smith, M.J. (Amsterdam: Elsevier Science Publishers) pp. 394-401.

Nielsen, J. (2006) "Quantitative Studies: How Many Users to Test?" In Alertbox, June 26 2006, Retrieved 30 July, 2007, from http://www.useit.com/alertbox/quantitative_testing.html

Ochoa, X. and Duval, E. (2007), "Relevance Ranking Metrics for Learning Objects", In *Proceedings of the Second European Conference on Technology Enhanced Learning*, edited by Klamma, R., Duval, E. and Wolpers, M. (London, UK: Spinger-Verslag), pp. 262-276

Ochoa, X. and Duval, E. (2006) , "Use of contextualized attention metadata for ranking and recommending learning objects", In *Proceedings of the 1st international workshop on Contextualized attention metadata*, edited by Duval, E., Najjar, J. and Wolpers, M. (New York, NY, USA: ACM press), pp. 9-16 http://portal.acm.org/citation.cfm?id=1183608

Robson, R. (2004) "Context and the Role of Standards in Increasing the Value of Learning Objects", chapter in *Online Education Using Learning Objects*, edited by McGreal, R. (London: Routledge/Falmer), pp. http://www.eduworks.com/Documents/Publications/McGreal_book_Robson_chapte.pdf

Rockley, A. (2002) Managing Enterprise Content: A Unified Content Strategy (Indianapolis: New Riders)

Schluep, S. (2005). Modularization and structured markup for web-based learning content in an academic environment. (Aachen: Shaker Verlag) http://e-collection.ethbib.ethz.ch/ecol-pool/diss/fulltext/eth16062.pdf

SCORM. (2004). *Sharable Content Object Reference Model*, Retrieved June 23, 2007, from http://www.adlnet.org.

Shivakumar, N., and Garcia-Molina, H. (1995), "SCAM: A Copy Detection Mechanism for Digital Documents", In *Proceedings of the Second Annual Conference on the Theory and Practice of Digital Libraries*. http://citeseer.ist.psu.edu/shivakumar95scam.html

Shrout, P. E., & Fleiss, J. L. (1979). Intraclass Correlations: Uses in Assessing Rater Reliability. Psychological Bulletin, Vol. 68, No. 2, 420-428.

Ternier, S. Neven, F. and Duval, E. (2003), "Web services for Learning Object Repositories: a Case Study - the ARIADNE Knowledge Pool System", in *Proceedings of Twelfth International World Wide Web Conference*, edited by King, I. and Maray, T. (New York, NY, USA: ACM Press), pp. 203-204 http://www2003.org/cdrom/papers/poster/p203/WWW2003%20Poster.htm

Verbert, K. and Duval, E. "ALOCOM: a Generic Onotlogy for Learning Objects". Submitted to the Special Issue on Digital Libraries and Education

Vercoustre, A., and McLean, A. (2005). "Reusing Educational Material for Teaching and Learning: Current Approaches and Directions." International Journal on E-Learning, Vol. 4, No. 1, 57-68. http://www.cs.usyd.edu.au/~aied/vol10/vol10_VercoustreMcLean.pdf

Wolpers, M., Najjar, J., Verbert, K. and Duval, E. (2007), "Tracking actual usage: the attention metadata approach", In *Educational Technology and Society [SSCI indexed Journal ISSN: 1436-4522 (online) and 1176-3647 (print)] Special Issue on "Advanced Technologies for Life-Long Learning"*.

Yan, K., Sukthankar, R., and Huston, L. (2004), "Efficient Near-duplicate Detection and Subimage Retrieval," In *Proceedings of ACM International Conference on Multimedia*, edited by Schulzrinne, H., Dimitrova, N., Sasse, A., Moon, S.B., Lienhart, R. (New York, NY, USA: ACM press), pp. 869-876 http://portal.acm.org/citation.cfm?coll=GUIDE&dl=GUIDE&id=1027729

Notes

[1] ALOCOM http://ariadne.cs.kuleuven.be/alocom

[2] Camtasia Studio http://www.techsmith.com/camtasia.asp

[3] ProLearn. "Prolearn Network of Excellence on professional learning", http://www.prolearn-project.org/

[4] RELOAD editor. *Reusable eLearning Object Authoring and Delivery*. http://www.reload.ac.uk/editor.html

[5] Slide Executive. *The PowerPoint Presentation Management Library* http://www.slideexecutive.com/

[6] Vasont Systems. http://www.vasont.com/

[7] Visual Studio Tools for Office. http://msdn2.microsoft.com/en-us/library/d2tx7z6d.aspx