Using Information Visualization for Accessing Learning Object Repositories

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Abstract

Learning objects are entities that may be used for learning, education or training. Nowadays they are often stored in Learning Object Repositories (LORs), such as the Ariadne Knowledge Pool System (KPS) [19], Merlot and EdNa. Typically users can search for learning objects in those LORs by filling out an electronic form that enables them to compose Boolean combinations of search criteria. More research is needed on novel access paradigms to enable more effective and flexible access to these repositories. In this paper, we investigate how we can use information visualization techniques for this purpose. We discuss the use of three existing information visualization techniques that we applied to the ARIADNE Knowledge Pool System (KPS).

Keywords--- learning objects, learning object repositories, information visualization.

1. Introduction

According to the Learning Object Metadata (LOM) standard, a learning object is ‘any entity, digital or non-digital, that may be used for learning, education or training’ [1]. This definition allows for an extremely wide variety of granularities. This means that a learning object could be a picture of the Mona Lisa, a document on the Mona Lisa (that includes the picture), a course module on da Vinci, a complete course on art history, or even a 4 year master curriculum on western culture [2].

Learning objects are stored in Learning Object Repositories (LORs) together with extensive metadata (e.g. LOM) that describes them. A few examples of such LORs are the Ariadne Knowledge Pool System (KPS) [19] [23], Merlot [20], EdNA [21], Universal/educaNext [22], etc. Students and teachers are able to search for learning objects in those LORs, based on the metadata-elements that describe the learning objects.

In most of those systems, there are two ways for users to search. The first one is to formulate a simple or an advanced query by filling out an electronic form that enables end users to compose boolean combinations of search criteria. The second one is to perform a kind of directory or category search by browsing the learning objects by subject. The resulting set of learning objects are always presented in a traditional results list.

It is clear that there is a need for more research on novel access paradigms that enable an end user to zoom in on relevant learning objects without requiring him or her to go through a lengthy process to formulate complex search criteria, to evaluate some of the results, refine the search criteria, etc. Information Visualization can improve this kind of access to LORs by enabling end users to manipulate controls over the metadata, zoom in on potentially more relevant learning objects and continuously keep an overview of how additional search criteria restrict the remaining number of learning objects [2].

We will start this paper in section 2 with a discussion of the strategies users can follow to access LORs. In section 3, we will compare three information visualization techniques that we have applied to the Ariadne KPS [19] [23]. In section 4 we will discuss a few techniques for manipulating controls over the metadata.

2. Access strategies

There are a number of ways of accessing a LOR. Imagine an end user, like a teacher, who wants to reuse a learning object in his own course. The first and traditional way is to start from an empty set of results and formulate a simple or an advanced query to get a number of results. The teacher can then evaluate some of the results and reformulate the query to filter out some results or include some others. This process of formulating queries and evaluating the results could be a lengthy process and is therefore rather time-consuming and user-unfriendly [2].
The second way is to start from a visualization of the complete LOR and filter out learning objects that are uninteresting by manipulating the metadata. This process should be highly interactive to be effective.

A combination of both these approaches is also possible. The user could start his search by entering a simple search criterion to make a first selection or filtering of the learning objects. The results of this simple search could be used as a good starting point for the visualization.

In the next section we will refer to these strategies when we compare a few information visualization techniques for visualizing learning object repositories.

3. Space Usage

It is important to investigate how we can use the available space to present the learning objects. We have to decide which elements of the available metadata are interesting to use in our visualization. Learning Object Metadata (LOM) [1] can contain a semantic classification of the subject of the learning object. For example the classification of the subject of a learning object about the Fibonacci-numbers could be:

- Exact, Natural and Engineering sciences
  - Informatics/Information Processing
  - General/Sundry.

This classification seems interesting to use as a starting point in visualizations of LORs because students and teachers typically search for learning objects of a particular topic. Besides that, they create a lot of useful subsets in the complete LOR, which are interesting to visualize. This classification could be used in combination with the second access strategy we mentioned in the previous section.

We will compare three visualization techniques that we have applied to the Ariadne KPS. These three techniques are squarified cushion tree-maps, hyperbolic trees and Venn-diagrams (Grokker). The reasons for choosing these rather straightforward visualization techniques are based on their characteristics [3] [14] [18]. We will use the techniques to visualize the semantic classification of the subject of the learning objects.

3.1. Squarified Cushion Tree-map

A tree-map is a visualization of hierarchical structure that makes 100% use of the available display space. It maps the complete hierarchy onto a rectangular region in a space-filling manner [3]. Cushion tree-maps inherit the elegance of standard tree-maps: compact, space-filling displays of hierarchical information, based on recursive subdivision of a rectangular image space. Intuitive shading is used to provide insight in the hierarchical structure [4].

We used the semantic classification we described above to cluster the learning objects in a tree-map. To be able to evaluate the use of a squarified cushion tree-map to visualize the Ariadne KPS, we implemented a coupling between a tree-map-library [5] and the KPS-Client of the Ariadne system [6] [7]. The result is shown in the figure 1.

In the visualization we use two colors, red and green, to visualize the usage rights of the learning object. The meaning of the red color is that the learning objects are restricted and therefore cannot be used by every user. The green color means that every user can use the learning object freely. The choice of this metadata-field is illustrative.

The users are able to zoom in on elements of their interest. Tooltips, a standard way to visualize extra information, are provided with basic information about the learning objects: title, author, and identifier. By clicking on the learning object, the user can view the complete metadata in his web-browser.

![Figure 1: Squarified Cushion Tree-map of the Ariadne KPS](image1)

The access strategy that was adopted in this example is the second one we described above: the user starts with a visualization of the complete LOR. At that point, he should be able to filter out learning objects that are not of interest by manipulating the metadata. However this necessary functionality is not yet available in the prototype.

3.1.1. The advantages of a tree-map for accessing and visualizing a LOR are the following:

- It provides an overall view of the entire LOR. So it allows users to move rapidly to any location in the LOR without getting lost.
• It is easy to add extra levels to the hierarchy, based on the query or the metadata-manipulation that the users perform. It would for example be easy to add a level that represents the granularity of the learning objects. The granularity of a learning object could be one of the following: raw media element, course, lesson, ….

• An extra level of information about the learning objects could be provided by using colors. We could use almost every metadata-field for this purpose. Most interesting would for instance be to use colors to represent the language or the usage right of the learning object. Imagine e.g. a teacher who searches a learning object to use in his economy class. Typically such a user does not want to lose much time by searching for such a learning object. In figure 1 the learning objects on the economy-topic are represented in the right rectangle. The teacher can immediately see that many of the learning objects are represented in a red color and therefore cannot be used freely.

• It’s easy to control. The user can easily navigate in the learning object space by zooming in or out interesting areas.

• No space is lost in this kind of visualization. It makes use of every available pixel.

3.1.2. Disadvantages of using a squarified cushion tree-map to visualize a LOR are the following:

• When just using the semantic classification of the subjects to cluster the learning objects, there are too many learning objects in one level. This is useful if the user wants answers to general questions about the contents of a complete LOR like:
  o How many learning objects does it contain on biology or chemistry?
  o Can I use most of the learning objects in this domain or are they restricted?
  o Are most of the learning objects complete courses or are they just short lessons.

These answers give general information about the complete set of learning objects of the repository. However if the user searches for individual learning objects on a specific subject, the use of this classification for visualizing the LOR does not cluster the learning objects well enough. The user will have to evaluate too many learning objects at the deepest level of the tree-map.

• The prototype lacks the necessary controls to be able to filter out uninteresting learning objects by manipulating the metadata of the learning objects. Therefore the tree-map visualization should be combined with other methods. Data sliders [8] or magical lenses [9] for example could be used for this purpose.

• We mentioned that we used the second access-method in the prototype. The prototype is coupled on a LOR with about 4500 learning objects. However much research is done on the interoperability of LORs [10] [11]. So, in the future we will easily have tens of thousands learning objects. The visualization should still be highly interactive so that the user can filter out uninteresting learning objects efficiently. This performance-issue could become a real challenge.

• Because of the number of learning objects that have to be presented, it is difficult to use other visual cues than colors. Extra visual cues could be pictograms that can be used to e.g. show the mime-type of the learning objects. This can be solved in two ways. First of all we could combine the visualization technique with extra controls to manipulate the metadata as described above. With these controls the user should be able to filter out many learning objects. In this way the screen areas available to represent the different learning objects will increase and there will be extra place to add visual cues. Alternatively, we could use distortion techniques [12] like fisheye-views [13] to give extra space to the learning objects.

3.2. Hyperbolic tree

A hyperbolic tree is a focus+context technique based on hyperbolic geometry for visualizing and manipulating large hierarchies [14]. Users can navigate through the hyperbolic tree by clicking on the nodes of interest. By doing so, the user brings those nodes into focus at the center.

To cluster the learning objects in a hyperbolic tree, we used the same semantic classification of the subjects of the learning objects as described before. The access strategy that was adopted was again the second one. To be able to evaluate the usage of hyperbolic trees for visualizing the contents of LORs, we made a coupling between a hypertree-library [15] and the KPS-Client of the Ariadne system [6] [7]. The result is shown in the figure 2. By clicking on a node that represents a learning object, the user can view its complete metadata in his web browser.

It was immediately clear that using the semantic classification was not useful when searching for specific individual learning objects because the number of internal nodes was too small and as a result there were too many leaf-nodes with the same parent-node. This is shown in figure 3.
Therefore we could use the third access strategy that we discussed before: The user first enters a simple search criterion and the results of that simple query are used as a start for the visualization. However it is still possible to have too few internal nodes in this case. The user could for example use a name of an author as the first simple query. It is likely that an author indexes most of his learning objects with the same semantic classification. Most of the leaf-nodes in this case would then belong to the same parent-node. This example shows that using the third strategy is not always a solution for this problem.

Another possibility is to give the users the opportunity to choose themselves. They should be able to select these metadata elements efficiently at the moment of the query or in some kind of customizable user-profile so that they will not have to select it every time they access the LOR. A user could e.g. choose the metadata-fields granularity, document language and author, to cluster the learning objects.

3.2.1. The advantages of using a hyperbolic tree with the strategy described above are the following:

- The user can choose the metadata elements that should be used to cluster the learning objects in the hyperbolic tree.
- Colors can be used as visual cues to show extra information.
- It is easy to navigate through the tree. Users can browse through the tree and select the learning objects of their interest.
- Tooltips can be used to show extra information.

3.2.2. Disadvantages of using hyperbolic trees are the following:

- When the user makes a bad choice of which metadata elements to use in the hyperbolic tree, the results will not be clustered in a nice way and again, there will be too few internal nodes. The user will then lose time.
- More space gets wasted than the tree-map visualization, but not in a problematic way because the user can easily browse to the space and the space will be dynamically reallocated.
- The visual space for each node is too small to add textual information like document titles, authors, publication dates, etc.
- When too many metadata elements are added to the hyperbolic tree, the user’s overview could degrade. When there are 5 or 6 levels and the user already browsed to the fifth level, he has to remember the top-levels of the hyperbolic tree to be able to make a good choice of the learning objects.

3.3. Venn diagrams

We could also visualize the learning objects of a repository with Venn diagrams. A Venn diagram is an illustration of the relationships between and among sets or groups of objects that share some or all characteristics.

Grokker [18] is a program that contains an interface that makes use of non-intersecting Venn-diagrams. Navigating through the diagrams is possible by clicking on the set of the user’s interest. Grokker will then zoom
in on that particular set. We used Grokker to evaluate this kind of visualization for the access to LORs. We did not couple the KPS-Client of the Ariadne system [6] [7] with Grokker yet because, at this moment, the Grokker-toolkit to write plugins for Grokker was not available. Therefore we manually made a diagram of the complete semantic classification of the subjects of the learning objects to be able to evaluate the visualization.

The access strategy was again the second one. Because we did not couple the KPS-Client with Grokker, we did not add all the learning objects in this visualization of the LOR. The result is shown in figure 4. Obviously, in the future, we should evaluate a complete visualization of the LOR with all learning objects included. However, we can already see some trends in this version.

This is shown in figure 5 where the user has to remember the complete classification of the subject of the learning object by remembering how he navigated to this point in the visualization.

- Using the semantic classification to visualize the learning objects in a Venn diagram is not the most useful classification to visualize or structure the learning objects. There are too few inner nodes or in this case top-level sets. This can be seen in figure 5. In this figure you can see again that a lot of space is wasted in the middle. So the semantic classification is not enough to structure the learning objects.

4. Manipulating metadata

In the previous section we compared a few information visualization techniques for presenting the learning objects in a LOR. These techniques look promising to enable a more flexible access to LORs. However, these visualizations are not enough. They should be combined with methods to manipulate controls over the metadata elements that are used to cluster the learning objects. With these methods, the users should be able to adapt the kind of clustering that is used in the visualization as we described in the section about hyperbolic trees. They should also enable users to filter out learning objects that are not of their interest. However these methods were not taken into account in the prototypes.

3.3.1. The advantages of using Venn diagrams to visualize the LOR are the following:

- Easy to filter out uninteresting learning objects by using colors.
- Colors can be used as visual cues to show extra information.
- Tooltips can be used to add extra information.

3.3.2. Disadvantages of using Venn diagrams (Grokker) are these:

- When using the semantic classification of the subject as a basis to cluster the results, a lot of space is wasted. You can clearly see this in figure 4 where almost 50% of the screen is not used to represent information.
- When completely zoomed in on a diagram, it is difficult to keep an overview of the complete LOR.

We already mentioned some existing methods such as the use of data sliders [8] and magical lenses [9]. We could e.g. use a data slider to manipulate the metadata-field ‘document language’. The user could then easily filter out all languages but English. A magical lens
could also be used for this metadata-field. When applying this method to the tree-map visualization, the lens could be moved over the learning objects in the map. The learning objects under the lens would then get the color that represents the appropriate ‘document language’.

Conclusions

In this paper, we investigated how we could use information visualization techniques to improve the access to learning object repositories. We used the semantic classifications of the subjects of the learning objects to cluster them together. Using this classification only seems interesting when the users are looking for general information about the complete LOR. When they are searching for specific individual learning objects, using this classification to cluster them does not suffice. Therefore we plan to further investigate how we can use the metadata to create interesting subsets of learning objects.

We compared three information visualization techniques for visualizing a LOR: tree-maps, hyperbolic trees and Venn-diagrams. Venn-diagrams are the least interesting because users can lose the overview of the LOR and on top of that, a lot of space is not used for representing information. Tree-maps and hyperbolic trees on the other hand, are more interesting but only when they are used in combination with methods to manipulate controls over the metadata elements that are used to cluster the learning objects.

The use of these visualization techniques will be empirically evaluated with extensive user studies. We will also complete the prototypes and extend them with the mentioned metadata manipulation techniques.

This research will hopefully result in more effective and flexible access to learning object repositories.

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References