

# INTELLIGENT VISUALIZATION TECHNIQUES FOR REUSABLE LEARNING OBJECTS TO FACILITATE ONLINE LEARNING ENVIRONMENT

**VINCENT TAM, RICKY MAK**

*Department of Electrical and Electronic Engineering  
The University of Hong Kong*

**ALVIN KWAN**

*Division of Information and Technology Studies, Faculty of Education  
The University of Hong Kong*

## Abstract

The idea of learning objects and its working standardization for the Learning Object Metadata as recommended by the IEEE 1484 provide a conceptual and implementation platform to promote reuse of learning resources with the latest educational technology. These significant changes undoubtedly affect the design of e-learning systems where learning resources like course or quiz materials can be conveniently anchored on a network of well-defined learning objects. In real-world learning object repositories like the MERLOT, each repository may consist of thousands or even tens of thousands of potentially inter-related learning objects, with some learning objects being components of other “high-level” learning objects. To allow the designers of those e-learning systems to restructure the network of learning objects for better reuse and re-purpose existing resources, greater accessibility or faster navigation, and more importantly facilitating both educators and learners to quickly identify some important relation(s) among the involved learning objects (or concepts), adaptive information visualization techniques can help. Through the adaptive visualization, users can focus on some subsets of learning objects with interesting properties for careful analysis. In this paper, we enhance the well-known force scan algorithm for integration with effective heuristics to produce appropriate diagrams of different scales or shapes for visualizing the relations among various learning objects. For rare cases where only independent learning objects are involved, our goal is to improve the visibility by evenly spreading out the learning objects as nodes with adjustable angular displacement while avoiding node overlapping on the different levels. However, for practical diagrams of related learning objects, the main challenge is to avoid both node and edge overlapping while spreading out the concerned learning objects on pre-assigned levels. In both cases, our adaptive visualization algorithms work with their best efforts to preserve the mental map of the initial diagrams for learning objects. We implemented prototypes of the two adaptive visualization algorithms in C++, and evaluated their performance on both random and real test cases whenever available. Their experimental results revealed the strength of our proposal for which e-learning systems can be greatly benefited. More importantly, it shed light on several interesting directions for further investigation.

## Introduction

High-quality learning content is costly to develop but it is often hard to be exchanged and reused by both instructors and learners due to the lack of a common format. Sharing of learning content between different e-learning systems is thus difficult. A number of concerning organizations like the IMS

-- DRAFT --

Global, Ariadne, and Institute of Electrical and Electronics Engineers (IEEE), have proposed ways, mainly through standardization, to tackle the problems. In particular, the ideas of learning objects and its working standardization for the Learning Object Metadata (LOM) as recommended by the IEEE 1484 (IEEE-1484, 2004) provide a conceptual and implementation platform for learning content reuse. To enhance reusability, learning objects are defined in different granular or aggregation levels. Low-level learning objects are typically content-driven where high-level learning objects tend to be more instructions-driven. Figures 1(a) and 1(b) illustrate the object hierarchy of two learning objects, a computer system and its hardware subsystem, which is a particular type of object relationships. In general, the number of levels of decomposition for learning objects depends much on the level of details required for specific applications, and the expected performance criteria for the resulting e-learning systems such as ease of understanding of the involved relations from the learners' perspective, efficiency/effectiveness of retrieval of relevant learning objects, etc. Some of these performance criteria are trade-offs to each other.

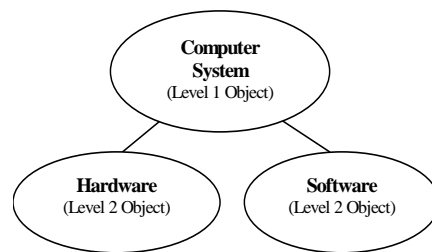


Figure 1(a). A Computer System

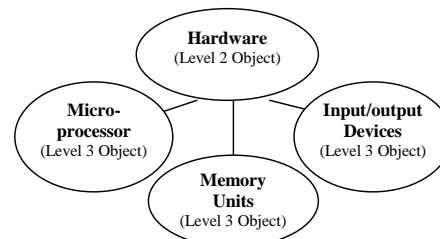


Fig. 1(b) The Hardware Subsystem

Given a learning object repository, a request for learning content can be fulfilled in essentially three ways.

1. The request for learning content can be met by some existing learning object(s) in the repository.
2. A new learning object is to be developed because the requested content cannot be found in the repository.
3. A part of the requested content can be found in the existing repository. The missing part is to be implemented by either developing a new learning object or revising some existing learning object(s).

-- DRAFT --

In the above cases, it is important to know what learning content is available in the learning object repository. In real-world learning object repositories, thousands or even tens of thousands of interrelated learning objects may be stored in each repository. For example, MERLOT contains more than 14,800 learning objects. Such a vast number of learning objects impose a challenge to the repository administrator when trying to examine the objects' hierarchy and inter-relationship. A suitable visualization tool that allows flexible viewing of selected repository objects at some particular aggregation level(s) will be very useful. Unfortunately the research community has paid little attention in this research arena according to our knowledge. This paper aims to address this important research area and reports some preliminary results regarding how graphical blocks that represent learning objects and their relationships can be displayed on a screen neatly.

It is worth noting that learning objects visualization is not the only challenge to the development of an effective learning object repository. Object classification with the use of suitable meta-data poses another challenge but it is out of the scope of this study.

Information visualization techniques (Sugiyama, 2002) have been extensively used in many different areas for a better understanding of organizational structures or system behaviors including the file structures in computers (Shneiderman, 1998), complex molecular structures in biochemistry (Shneiderman, 1998), navigation of complex software structures (Eades, *et al*, 2005). The goal is usually to provide the most flexible views of the objects involved in the underlying applications so as to facilitate the careful and detailed analysis performed by the domain experts through different representations of the notated data items. In this research, as the first attempt to provide effective visualization techniques for any general hierarchy/network of learning object, we adapted the well-known force-scan algorithm (Misue, *et al*, 1995) that has been previously modified for the online viewing of the possibly complex relationship among web pages (Huang, *et al*, 1999), for which each web page may possibly represent a concept or learning object. As different from the modified FSA (Huang, *et al*, 1999), our adapted FSA is not constrained to hierarchical structures. Instead, our adapted FSA is based on concentric rings of various flexible shapes including circles, eclipses, or even rectangles to suit the underlying application or screen sizes. Each concentric ring may denote the same or different level for the learning objects involved. The main idea is to use an adaptive "repulsive" force among the possibly overlapping nodes, i.e. learning objects, at the same level from the innermost to the outer level(s) to produce an initial and feasible solution without any node overlapping. For those

**-- DRAFT--**

nodes that are being connected by edges to denote certain relations, the second phase of swapping will be executed to reduce the total number of edge crossings until a local minimum is reached. In any case, our adaptive FSA aims to produce a visually appealing network of learning objects for better understanding of the interactions involved. We implemented various prototypes of our adapted FSA based on different aesthetic criteria, and gave an empirical evaluation of their performance on various randomly generated or real-life test cases to demonstrate the flexibility of our proposal.

This chapter is organized as follows. The next section reviews some previous works relevant to our proposal. The third section details our adaptive proposal of intelligent visualization techniques for learning objects. We give an empirical evaluation of our proposal on various test cases in the fourth section. In the last section, we summarize our work and shed lights on future directions.

### **Related Works**

In this section, we will consider some related works including the basic concept of a mental map, the original force scan algorithm (FSA), that has been adapted for viewing the relationship among web pages, and later the learning objects and existing visualization tools available for studying the relationship between them in order to provide the background information for our subsequent discussion.

#### ***Mental map***

The concept of a mental map was first introduced in (Eades, *et al*, 1991). A mental map can be thought of as the presentation of a person's mind. Intrinsically, an individual's understanding of the relationship among different learning objects can be portrayed in a mental map. (Lee, *et al*, 2006) pointed out that without adequate consideration of the notion of mental map when redrawing a modified graph, users often have to spend a lot of time relearning the redrawn graphs. To explicate a mental map, a graph representation is typically used. The usefulness of graph presentations like hierarchy graph or flow diagrams depends heavily on the quality of the layout of the graphs (Misue, *et al*, 1995), i.e. whether nodes and edges are placed in a pleasing way. Davidson and Harel (Davidson, 1996) refer to a nice-looking graph drawing as a drawing which: (1) distributes nodes evenly, (2) makes edge-lengths uniform, (3) minimizes edge-crossings, and (4) keeps nodes from coming too close to edges. We adopted some of these considerations when designing our learning objects visualization algorithm.

-- DRAFT--

### ***The Force Scan Algorithm***

The original force-scan algorithm (Misue, *et al*, 1995) was inspired by the physical forces such as the spring-like elastic forces existed between molecules, that will always reach equilibrium (i.e. the globally minimal energy state) after any external stimulus. Basically, the FSA works by scanning and propagating the “repulsive” force (i.e. the distance) required to remove node overlapping along the  $x$ - or  $y$ -direction in each step. The step is repeated until all the overlapping is removed. FSA was later modified for the online viewing of the possibly complex relationship among web pages (Huang, *et al*, 1999), for which each web page may possibly represent a concept or learning object. In this work, we investigate how to adapt the original FSA specifically for displaying learning objects and their relationship in the most flexible manner on a screen of reasonable size and shape. It is worth noting that in some cases with “closely” related learning objects, our adapted FSA needs to be augmented with a heuristic-based swapping algorithm that works to reduce the total number of edge overlapping for ease of viewing the relations among the learning objects.

### ***Visualization for learning objects***

With the growing concern over learning objects, the research community has been working hard to define standards for learning objects, including the description standard as contained in the IEEE 1484 standard (IEEE-1484, 2004), to facilitate the realization of learning object concepts in actual e-learning systems. As we pointed out in the previous section, as the implementation of learning objects is still at its infancy, and without much explicit experience to guide the design stage, it becomes extremely important to have an effective visualization tool so as to help the designers to determine the appropriate levels of structural complexity of learning objects for each specific application. Up to our knowledge, there is no existing visualization tool available for learning objects. In some case, researchers were forced to use existing knowledge management tools like the Ariadne KPS (Ariadne, 2004) to view the relationship among the involved learning objects or concepts. Clearly, this temporary fix can never provide any adaptive and flexible solution to view the learning objects and their relationship for any careful analysis.

### **Intelligent Visualization Techniques for Learning Objects**

Basically, we adapted the original FSA for systematic placement of nodes (as rectangular boxes) representing different learning objects on various levels of concentric rings of any shape including circles, eclipses or even rectangles to flexibly suit the underlying screen sizes and/or preferences of individual users. Since learning objects are associated with different aggregation levels, it could

**-- DRAFT --**

be a nice idea if the learning objects of the same or similar aggregation levels can be grouped in the same or adjacent concentric rings so as to achieve a better perceptual grouping.

Our intelligent visualization method starts with initial and random positions of objects along the first concentric ring in which some objects may be overlapped. The algorithm would then scan along the circumference and push away the overlapped objects. The “push” force is set to be proportional to the “angle of overlapping”, which equals to the angular difference of the same object before and after the overlapping is removed. It is always possible to introduce a gap size between any adjacent pair of rectangular boxes (objects) by adjusting the “pushing force”, i.e. a stronger push to insert a bigger gap. After the placement of objects on the first ring is completed, the remaining objects will be pushed onto the second ring with the continuous adjustment by our adapted FSA until there is no unarranged object. This forms an initial mental map of the learning objects for further enhancement. In cases where the “minimal” angular displacement is applied (in the compact mode of our adapted FSA) to remove node overlapping, a “compact” and initial mental map is obtained. On the other hand, when the predetermined “regular” angular adjustment is used (in the regular-angle mode of our adapted FSA) to remove node overlapping, a “regular” mental map is produced. Nevertheless, it should be noted that such initial mental map of learning objects, no matter based on the minimal or regular angular adjustment to remove node overlapping, simply guarantee no *intra-ring* node overlapping along the same concentric ring. *Inter-ring* node overlapping may still exist between nodes on neighboring rings unless a sufficiently large inter-ring distance is preset that will then lead to wastage of display area on a specific screen. Besides, with the difference in the perimeter of individual rings, the number of learning objects distributed on the various rings may not be well-balanced. In other words, this initial mental map of learning objects is often far from visually appealing and thus needs the second phase for refinement.

In the second phase, the adapted FSA will compute the minimal inter-ring distance for each pair of adjacent rings until no *inter-ring* node overlapping occurs while fulfilling other aesthetic criteria such as making the nodes as evenly distributed as possible for the visual comfort. It is interesting to note that for the regular-angle mode of our adapted FSA, the inter-ring node overlapping may sometimes be solved by simply rotating one of the adjacent rings clockwise or anti-clockwise.

-- DRAFT--

Lastly, when there is any connection between the nodes, i.e. some relation existed between the learning objects of various levels, our visualization technique will try out different swapping based on certain heuristic, like related nodes being placed as locally close to each other as possible, to minimize on the total number of edge overlapping that has been known as a very challenging problem in Information Visualization. Figure 2 shows the pseudo-code of our adapted FSA using the compact mode. *Learning\_Objects* is the set of learning objects to be displaced by the function *Adapted\_FSA\_in\_Compact\_Mode(..)* to form the ultimate mental map whereas the *Obj\_Relations* specifies the set of edges/relations between any pair of involved learning objects.

---

```
Adapted_FSA_in_Compact_Mode(Learning_Objects, Obj_Relations)
BEGIN
  foreach (obj in Learning_Objects)
    apply the minimal angular adjustment to remove all intra-ring node
    overlapping
  foreach (ring in the initial mental map)
    compute the minimal inter-ring distance to remove all inter-ring node
    overlapping
  foreach (rel in Obj_Relations)
    swap two nodes chosen according to a predefined heuristic to reduce the
    number of edge overlapping
END
```

---

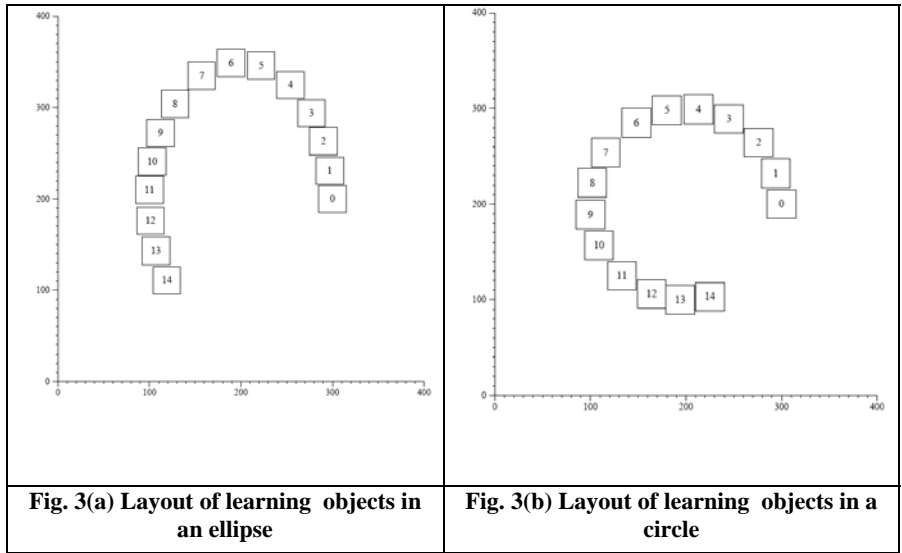
**Figure 2. The pseudo-code of our adapted FSA using the compact mode**

### **Empirical Evaluation**

We implemented our intelligent visualization method adapted from the original FSA in C++, and ran on a number of randomly generated or real-life test cases on the IBM notebook PC (model X31) installed with the Windows XP operating system.

Figure 3(a) and 3(b) show the resulting layouts of a randomly generated test case involving 14 learning objects of the same level. Obviously, our adaptive approach can flexibly arrange the nodes into any regular shapes to suit the underlying screen size or user's requirement.

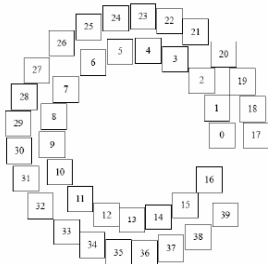
-- DRAFT --



The 3 variants as described in the previous section were detailed as follows.

1. Compact mode – it aims to save most space, but nodes may be placed in a less even way.
2. Regular-angle mode – it arranges nodes in all rings with equal angular distance.
3. Even spread mode – it spreads all nodes evenly, by roughly calculating the capacity of each ring to hold nodes.

Their results on circular layouts of 40 nodes are given in Figure 4(a) to 4(c).



**Figure 4(a). Compact mode.**



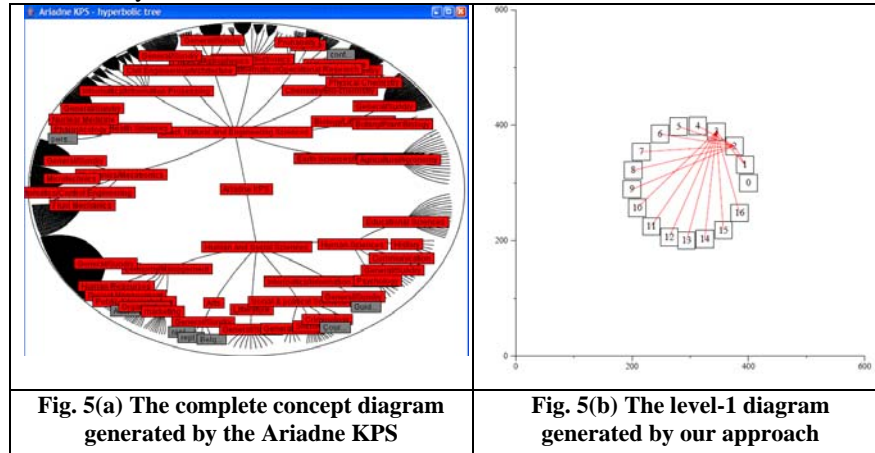
**Figure 4(b). Regular-angle mode.**



**Figure 4(c). Even spread mode.**

**-- DRAFT --**

Figure 5(a) and 5(b) compare the complex and fixed concept diagram generated by the Ariadne KPS system against the level-1 diagram flexibly generated by our approach. Undoubtedly, our approach is more flexible and suitable for careful analysis.



### Concluding Remarks

Unquestionably, learning objects and their working standards will improve on the future e-learning systems. One particular way is to reorganize the stored course materials or online discussion topics with anchors to a network of well-structured learning objects for fast navigation or retrieval of relevant concepts. As the development of learning objects is still at its infancy without much useful experience accumulated or guideline formulated, an effective visualization tool for learning objects becomes extremely important. In this paper, we propose to adapt the original force-scan algorithm for the flexible viewing of learning objects and their relations spanning across different levels. We implemented our prototype in C++ that provides customizable views of learning objects for critical analysis to support any design decision to be made by the software or database designer of existing or future e-learning systems.

There are several interesting directions for future investigation. First, it is interesting to investigate how to improve our proposed visualization techniques with other useful heuristics to minimize node/edge overlapping. Besides, applying local search methods like the simulated annealing or genetic algorithm to handle such visualization problems should be interesting. Lastly, it is worthwhile to study how to extend the capabilities of our proposal through providing many different kinds of diagrams for detailed analysis.

-- DRAFT --

## References

- Davidson, R. and Harel D. (1996): Drawing Graphs Nicely Using Simulated Annealing. *ACM Transactions on Graphics*, 15(4):301-331.
- Eades, P., Lai, W., Misue, K., and Sugiyama K. (1991). Preserving the Mental Map of a Diagram. *Proc. of Compugraphics*, 91: 24-33.
- Eades, P., Li, W.C., Hong, S.H., et al. (2005). Navigating Software Architectures with Constant Visual Complexity. *Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'05)*, p.248-252, Dallas, Texas, USA, 21 – 24 September 2005.
- Huang, M.L., Lai, W., Zhang, Y.C., et al. (1999). Mapping and Browsing the Web in a 2D Space. *Proceedings of DEXA Workshop*, 248-252.
- Lee, Y.-Y., Lin, C.-C. and Yen, H.-C. (2006). Mental Map Preserving Graph Drawing Using Simulated Annealing. In *Proc. Asia Pacific Symposium on Information Visualisation (APVIS2006)*, Tokyo, Japan. CRPIT, 60. Misue, K., Sugiyama, K. and Tanaka, J., Eds., ACS. 179-188.
- Misue, K., Eades, P., Lai, W., Sugiyama, K., et al. (1995). Layout Adjustment and the Mental Map. *Journal of Visual Languages & Computing*, 6(2), 183-210.
- Sugiyama, K. (2002). *Graph Drawing*. Japan, New York: World Scientific Press.
- Shneiderman, B. (1998). *Designing User Interface: strategies for effective human computer-interaction*. Reading, Massachusetts, Harlow, England, Sydney, Bonn: Addison Wesley.
- The Ariadne KPS Client. (2004). *Ariadne KPS as a hyperbolic tree*. Retrieved: May 5, 2005, from <http://ariadne.cs.kuleuven.be/infovis/casestudies.php>.
- The Working Committee of the IEEE 1484 LOM Standard. (2004). *The Learning Object Metadata Standard*. Retrieved: May 5, 2006, from <http://ieeeltsc.org/wg12LOM/>.

-- DRAFT--