Customizing Multimedia with Multi-Trees

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INTRODUCTION

The majority of multimedia applications rely on hypermedia technologies, such as HTML, XML, or PHP (cf. Lang, 2005, for a review on design issues of hypermedia systems). These technologies enable the presentation of any content such as entries in a digital encyclopedia or products on a company's homepage. In contrast to database queries, the hypermedia has to be navigated interactively. The navigation process frequently fails, and the user gets *lost in hyperspace*. This widespread phenomenon (Shneiderman & Plaisant, 2005) is caused mainly by an inadequate navigational design of the hypermedia. Making up an adequate navigational design becomes even more challenging if groups of users differ with respect to their knowledge of a topic's structure and if they have overlapping interests.

The navigational design comprises two components: the structure of the hypermedia and the layout of user interfaces. The latter aspect is the focus of usability studies (e.g., Falk & Sockel, 2005); whereas, the former is less frequently discussed in the literature and is given scent mention in lectures at universities or business schools. This article is mainly devoted to the former aspect, and:

- outlines the graph theoretic foundations for structuring hypermedia,
- introduces multi-trees for customizing hypermedia with respect to different user groups, and
- provides an overview of metrics to assess the navigational efforts of the user.

The approach presented herein differs from well-established human-computer interaction studies (e.g., Arroyo, Selker, & Wei, 2006), because it aims at quantifying the users' navigational efforts with respect to the structure of hypermedia systems rather than the interface design. This article presents a modeling approach, and all results are derived by a deductive analysis.

The remainder of this conceptual article is structured as follows: subsequently, the opportunities of structuring hypermedia are outlined. Then components of users' navigation efforts are discussed, and metrics for the assessment of navigational burdens are presented. Afterward, advantages of multi-trees are highlighted using a numerical example. Starting from a discussion of the limitations of this approach, avenues of future research are pinpointed. The final section provides the conclusions of this study.

STRUCTURING HYPERMEDIA

Hypermedia are networks comprising media objects (documents, pictures, films, etc.), pseudo-objects (pages for guiding the user), and links to interconnect media objects and pseudo-objects. In terms of graph theory, both media objects and pseudo-objects are nodes (or vertices) of a graph, which provide some content or navigational information for the user. The links are the edges of the graph, which enable navigation of hypermedia. Since the nodes are arbitrarily types of media (films, sounds documents, etc.), this simple organization scheme holds for many multimedia instances of our everyday life, of which the World Wide Web is clearly the most prominent.

For the design of adaptive hypermedia two types of nodes are distinguished (Brusilovsky, 2001; Muntean, 2005): navigational nodes and contents comprising nodes. If different types of media are knitted within one environment, the navigation within the media-objects has to be considered as well as the navigation between them. The subsequent considerations are restricted to the latter problem of reaching the individual media objects of interest, but do not address the complexity arising from the combination of different qualities of media objects.

An intuitive and straightforward organization would be a tree structure in which the entry node is the root and the media objects are the leaves. In this structure, all nodes that are not leaves are pseudo-objects. The Internet presents a variety of hierarchically structured organizations, such as companies and universities, although virtual product catalogs could also be structured in this manner. Unfortunately, this principle allows for one, and only one, path from the entry node to each of the leaves. Moreover, hypermedia designers have to be self-disciplined, resisting any temptation to cross-link the leaves. Empirical evidence suggests that the professionalism of hypermedia designers does not hold the quality level of commercial software design (Barry & Lang, 2001). This leads to instances fraught with disadvantages with regard to (1) navigability and (2) maintenance costs.

Clearly, the tree is not the only graph structure, but one of several that might be adopted to create a hypermedia system. Subsequently, the following structures are considered:

1. **Sequence:** In this structure, the nodes can be accessed in a predefined succession. The user has no opportunity to navigate by himself or herself (e.g., a guided tour).
2. **Tree:** The nodes are hierarchically structured. Therefore, the user can navigate by choosing one from the various links emanating from his or her current position node. In order to support this navigation, the links are usually annotated with a few meaningful keywords, symbols or pictures, or "information chunks," to provide the user with an impression of the contents in the nodes that might be reached following the particular link.
   Each node, with the exception of the leaves, has one or more descendant nodes, or "child nodes." The number of child nodes equals the number of links originating from a parent node, referred to as out-degree in the graph theoretic literature. The in-degree is equal to one for all nodes of a tree, with the exception of the root node. Therefore, a maximum of one path from each node to a descendant node is possible in a tree structure. Each tree is a mapping of a particular hierarchy. Obviously, the sequence is a tree with an out-degree equal to one.
3. **Multi-Tree:** In contrast to the previously mentioned trees, the multi-tree structure allows for more than one father node in the graph. Consequently, a media object can be reached by traversing more than one distinct path of the graph. If, for instance, user groups (customers, suppliers, employees, investors, etc.) can be characterized by their interests, their read or write permissions, or their knowledge of the structure, it is straightforward to define an access path for each user group. A multi-tree is made up of overlapping, identical branches of group-specific trees. Thus, redundancies are avoided and maintenance costs are kept at a minimum (Furnas & Zacks, 1994). Moreover, the navigational burdens of the user are reduced because they are restricted to a sub-graph. Understanding the structure of this sub-graph and developing a mental model is always easier than comprehending the complete graph (Otter & Johnson, 2000).
4. **Net:** A net is the most general form of graphs. All the topologies outlined previously are special cases of nets. If all nodes of a net are linked to one another, the user benefits from maximal flexibility, but is likely to suffer from information overload. The number of links, from which he or she has to make a choice, equals the overall number of nodes. Therefore, in a net of *n* nodes, the user has to process *n*-1 information chunks in the absence of any support provided by a hierarchical structure. Usually, only some index nodes or site maps are linked to all, or almost all, the other nodes. However, even these pseudo-objects, for the most part, provide the user with a hierarchical, or at least alphabetical, order of the linked nodes. Of course, fully connected net structures are not adopted to interconnect multimedia objects, but net structures commonly arise by adding links in an unstructured manner during the creation, extension, or updating of hypermedia.

McGuffin and Schraefel (2004) provide an overview of further mathematical topologies for structuring hypermedia.

NAVIGATION EFFORTS

For the assessment of already existing hypermedia, a variety of techniques, including cognitive walk-through, action analysis, or think-aloud, has been proposed (Holzinger, 2005). Commonly used metrics are (1) search time spent to assess a media object when starting from the entry node, (2) the number of key strokes needed in assessing the media object, (3) the retention time in the nodes, and (4) the number of recurrences to a particular node (Card, Moran, & Newell, 1983).