

Cultural Adaption of Hypermedia: A Contemporary State of the Art of Industrial Practice and Improvements by Multi-Trees

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ABSTRACT

Culturally adapted hypermedia design attracts increasing scientific attention. Complementing the conventional human-computer interaction studies we investigate the current state of companies' cultural adaptation of their websites. This study evaluates a sample of 215 websites with respect to design and navigational aspects. Subsequently, we discuss the possibilities of structuring hypermedia and enabling the adaptation to culturally bounded user expectations. Moreover, we introduce metrics for assessing navigational burdens and outline the advantages of multi-trees for structuring hypermedia.

Keywords: Culture, Hypermedia, Information Chunks, Multi-Trees, Navigation

INTRODUCTION

Hypermedia are networks comprising media objects (documents, pictures, films, flash animations, etc.), pseudo-objects (pages for guiding the user), and links to interconnect media objects and pseudo-objects (Wagner, 2008, p. 318). The majority of multimedia applications are based on hypermedia technologies such as HTML, XML, or PHP (see Lang, 2005, for a review of design issues of hypermedia systems).

These technologies enable the presentation of any content, such as entries in a digital encyclopedia or product and service descriptions on a company's website. In contrast to database queries, hypermedia are operated interactively (usually using a browser).

While the user expects to be guided through hypermedia efficiently, the increased flexibility of hyperspace frequently results in the user getting lost (Kim & Hirtle, 1995). This widespread phenomenon mainly results from

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the hypermedia's inadequate navigational design (Shneiderman & Plaisant, 2005) and the user's high cognitive load, as both conditions lead to disorientation. Creating an adequate navigational design becomes an ambitious task, as users differ markedly with respect to their knowledge of the content covered by the hypermedia, the technical facilities of their browser, and their device hardware. Further, users are not only likely to have overlapping interests, but they may well be from different cultures, as ongoing globalization increases the access by users world-wide who use hypermedia in commercial contexts, such as companies' homepages and virtual product catalogues (e.g., Heimgärtner, 2013; Lindgaard, Dudek, & Chan, 2013). These characteristics of users increase the importance of effective navigational design.

Navigational design includes two important aspects: the structure of hypermedia and the layout of user interfaces. While usability studies have frequently addressed considerations of layout, previous research has less often dealt with issues of structure. We emphasize the aspect of structure, tackling the challenge of intercultural communication by

- Clarifying the practical relevance of culture-related graphical interface design adaptation in comparison to the relevance of navigation-related adaptation to the user's cultural framing,
- Outlining the graph theoretic foundations for structuring hypermedia, and
- Introducing multi-trees as a tool for adapting hypermedia to the diverse needs of user groups.

This paper differs from well established human-computer interaction studies (HCI) in that rather than emphasizing interface design, we stress quantitative modeling of the users' navigational efforts. Our empirical results are derived by a deductive analysis and the analysis of 215 websites. Notably, we do not investigate the user's preferences or behavior, but instead challenge the current state of companies' cultural adaptation of their websites.

The remainder of this article has the following organization. Next, we outline the research design, the research hypotheses, and the results of our study. We then discuss the possibilities of structuring hypermedia with respect to distinct cultural user groups. We subsequently outline the components of users' navigation efforts and systematize the metrics for assessing navigational burdens. Using a numerical example, we highlight the advantages of multi-trees, which allow group-specific paths and reduce the user's exposure to complex navigation. In the final section, we provide the conclusions of the study.

The Need for Cultural Adaptation of Hypermedia

Previous investigators argue that the web is not a culturally neutral medium, but is "full of cultural markers that give country-specific websites a look and feel unique to the local culture" (Singh, Zhao, & Hu, 2003, p. 63). This statement pinpoints the challenge of addressing culturally influenced differences regarding the aspects of navigation and usability. Importantly, prior research indicates that culture has a substantial influence on the user's perception of the quality of a website's design. In particular, cultural adaptation of websites is necessary to reduce misinterpretation of symbols, colors, and sounds (Gould, Zakaria, & Yusof, 2000).

Most previous studies of the relationship of culture and hypermedia usability (e.g., Baber & Badre, 1998; Gould, Zakaria, & Yusof, 2000; Marcus & Gould, 2001; Hodemacher, Mandel, & Jarman, 2005; Cry, Bonnani, Bowes, & Ilsever, 2005) are based on national culture quantification according to the dimensions developed by Hofstede (1980). Since the empirical data for this well elaborated quantification scheme were obtained in a professional context, this scheme might serve well in business-to-business communication contexts. In contrast, the Schwartz (1999) value scheme provides a broader and more recent empirical basis as well as sound theoretical underpinnings. Other research (Baack & Singh, 2007) draws on both quantification schemes and takes advantage of

granular information captured by the Schwartz scheme. Our empirical research design is based on Schwartz's values scheme.

For our study, we selected five national cultures: Argentina (AR), India (IN), Mexico (ME), Philippines (PH) and the United States (US). Table 1 provides the national cultural assessment in terms of Schwartz's dimensions.

In this first step, we evaluate the common practices in website design with respect to cultural adaptation. We consider a set of 215 websites (for the list of companies included in this study, see appendix A), which we selected according to two criteria: (1) the hypermedia presents a national web representation of multinational active company, and (2) the company has a website in each of the five countries. Since all companies of any industry have to cope with the cultural settings of their target markets, we did not limit our sample with respect to a certain industry.

From the results of previous research, we develop two categories of hypotheses. In the first category are hypotheses that consider the interrelationship of culture and appearance of the interface by means of the visual gestalt elements. Hypotheses in the second category consider navigational aspects.

The cultural dimensions of *individualism/collectivism* (Hofstede, 1980) and *conservatism* (Schwartz, 1999) both capture the role of individuals and their affiliation to groups in national societies (Baack & Singh, 2007, p. 186). Individuals in conservative cultures prefer working in groups, and therefore in these societies hypermedia should use groups rather than

individuals as visual stimuli (Gould, Zakaria, & Yusof, 2000, p. 168). Therefore,

H1: In cultures scoring low on conservatism, single persons are shown as visual stimuli rather than groups.

Schwartz's (1999) value dimension of *hierarchy* is similar to Hofstede's (1980) *power distance*. Gould, Zakaria, and Yusof (2000, p. 165) state that users in high power distance cultures "want to know who is in charge of an organization and how it is staffed." Similarly, Singh, Zhao, and Hu (2003) provide evidence for the relevance of pictures of board members, and the like. Therefore,

H2: In cultures scoring high on hierarchy, photos of employees and explanations of their role will be included more frequently than in cultures scoring low on hierarchy.

The value of *mastery* captures the gender roles in the society and therefore is similar to the *masculinity/femininity* dimension defined by Hofstede (1980). According to the results of Marcus and Gould (2001, p. 16), a clear distinction of roles (e.g., males as managers, females as mothers and housewives) can be expected in cultures emphasizing mastery.

H3: In cultures scoring high on mastery, a clear distinction of gender roles is expressed in the visual stimuli.

Table 1. Cultural values according to Schwartz

	Conservatism	Hierarchy	Mastery	Affective Autonomy	Intellectual Autonomy	Egalitarianism	Harmony
AR	3.65	2.22	4.30	3.78	4.12	4.88	4.23
IN	4.00	3.24	4.30	3.54	4.06	4.50	3.98
ME	3.84	2.21	3.93	3.10	4.43	4.70	4.45
PH	4.03	2.75	3.80	3.09	3.94	4.60	4.03
US	3.64	2.63	4.15	3.94	4.28	4.71	3.78

The value of *intellectual autonomy* captures curiosity, broadmindedness, and creativity. These aspects directly relate to the use of colors in hypermedia design (Baack & Singh, 2007, p. 186).

H4: In cultures scoring high on intellectual autonomy, more colors will be used than in cultures scoring low on intellectual autonomy.

The second category of research hypotheses relates to navigational aspects. Prior research provides evidence that the opinions of others are strongly relevant in national cultures high in the value of *conservatism* (Gould, Zakaria, & Yusof, 2000; Singh, Zhao, & Hu, 2003). Consequently, websites should include or directly link to communities, forums, and chat rooms.

H5: Hypermedia for cultures scoring high in conservatism are more likely to embrace community-related features than hypermedia for cultures scoring low in conservatism.

The results of other studies indicate that the value of *harmony* (similar to the Hofstede-value *uncertainty avoidance*) has an impact on the perception of being “lost in hyperspace” (Gould, Zakaria, & Yusof, 2000; Singh, Zhao, & Hu, 2003). Therefore, our last hypothesis is:

H6: In cultures scoring high on harmony, the number of outgoing links is lower than in cultures scoring low on harmony.

We evaluated all six hypotheses using ANOVA and logit regression. Notably, the gestalt-related hypotheses (H1–H4) are rejected (at a level of $\alpha = .1$) for our data sample. However, the navigation-related hypotheses (H5 and H6) are not rejected. The first result appears to conflict with previous research, possibly because of conceptual differences. We used a different scheme to quantify the national cultures, and—more important—we did not investigate users’

preferences but instead provide an appraisal of today’s common communication practices.

From the second result (H5 and H6) we learn that practitioners need simple and efficient tools for the cultural adaptation of hypermedia navigation facilities. In the web a user’s national culture is easily determined by decoding users’ IP address. However, implementing various versions of hypermedia leads to redundancy and increases both maintenance burdens and costs. Consequently, we introduce the multi-tree as a tool for the cultural customization of hypermedia.

Structuring Hypermedia

In terms of graph theory, both media objects and pseudo-objects are nodes (or vertices) of a graph. Each node provides the user with some content-related or navigation-related information. The links are the edges of the graph, and the edges enable navigation of hypermedia.

Two types of nodes apply to the design of adaptive hypermedia (Brusilovsky, 2001; Muntean, 2005): navigational nodes and content-comprising nodes. Usually, websites are mixtures of different types of media (text, flash, documents, etc.). When a mixture of types is used, two kinds of navigation have to be included in the approach: the navigation within the media-objects and the navigation between them. In this study, we focus on the challenge of enabling the user to reach the media-objects of interest.

The web consists of a variety of hierarchically structured organizations, such as universities or companies, but also includes virtual product catalogues. A navigation process within such structures should be intuitive and straightforward—criteria that call for a tree structure with the entry node as the root and the media objects as the leaves. Nodes that are not leaves are defined as pseudo-objects. In any conventional tree structure, only one path can exist from the entry node to each of the leaves. Web designers have to be self-disciplined and resist any temptation to crosslink the leaves. However, web designers do not always meet

this requirement in their daily work. Empirical results suggest that hypermedia designers do not work on the same level of professionalism that has been reached in conventional software design (Barry & Lang, 2001; Al-Allaf, 2012). In their seminal paper on web engineering, Deshpande et al. (2002) provide a list of reasons for this lapse, ranging from insufficient specification of requirements to evolution of implementation environments to development team dynamics and the lack of management support. Notably, despite various design process models (Ceret, Dupuy-Chessa, Calvary & Rieu, 2013) have recently provided a taxonomy), the situation has not changed substantially, possibly owing to an abundance of complex concepts in combination with a lack of simple but ready to use tools. We propose multi-trees as an option to fill this gap, as they provide special advantages for adapting hypermedia to culturally related communication preferences.

Topologies

A tree is one of several graph structures available to address the problem of navigation. If all media-objects are considered as nodes and all existing relationships between the nodes are regarded as edges, the following four topologies can be distinguished:

1. **Sequence:** In this structure, the user can access the content only in a predefined order. The user is given no opportunity to navigate by himself or herself (as, for example, in a guided tour).
2. **Tree:** Owing to the hierarchically structured nodes, the user can navigate simply by choosing one of the numerous links provided at the current position's node. To support the user during navigation, the links are usually annotated with keywords, symbols or pictures, or "information chunks." Annotation provides the user with an impression of what following a particular link will lead to at the next node. Each node should have one or more descendant nodes, also called "child nodes."

The leaves do not have child nodes. The links emanating from a parent node equal the number that constitutes the out-degree. According to Wagner (2008), the in-degree is equal to one for all nodes of a tree, with the exception of the root node. Therefore, a tree structure allows a maximum of one path from each node to a descendant node. 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 navigation using the previously described trees, navigation to one media-object is possible on different paths of the graph. Consequently, the multi-tree structure allows more than one parent node in the graph. If user groups can be distinguished by, for example, interest or knowledge of the structure, it is important to define different access paths for the different user groups. A multi-tree comprises overlapping, identical branches of group-specific trees—a configuration that helps avoid redundancies and reduces maintenance costs (Furnas & Zacks, 1994). Additionally, a multi-tree reduces the user's navigational burdens because of it minimizes complexity: the user is restricted to a sub-graph with all information needed. 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:** The most general form of graphs is a net. All of the above topologies are special cases of nets. The user has maximum flexibility if all nodes of a net are linked to one another, but this linking also leads to an information overload since the user has to make a decision from the number of existing links, which equals the overall number of nodes. For this reason the user has to process $n-1$ information chunks in a net of n nodes without the benefit of a hierarchical structure or support. In the majority of cases, the user has very little access to assistance, and generally, some index nodes or site maps should be linked

to all nodes. Nevertheless the pseudo-objects provide the user with a hierarchy or an alphabetical order of the linked nodes. Although fully connected net structures are not a common feature of multimedia design, net structures usually develop as websites are created and links are added in an unstructured manner in an extension or updating process of the hypermedia.

Navigation Effort

Navigational errors serve to quantify the degree to which the user gets lost in hyperspace. For this quantification, rings, loops, and spikes are considered. A traversing path going back to the initial point is called a ring, and loops are rings embracing no smaller rings. A path that goes in one direction and then directly in the opposite direction is called a spike. These metrics are useful for checking and improving navigation in existing hypermedia, but they are nearly useless in the construction phase of new websites, before a site is implemented. Therefore, a priori criteria for constructing website navigation are needed.

Development of these criteria requires consideration of two distinct efforts: the movement effort of the user and the effort of estimating all offered links before choosing which one to follow.

Metrics for the movement efforts are the following (De Bra, 2000; Herder, 2002; Wagner 2008):

- *Distance* is given by the diameter of the graph. It is the maximum of all the shortest paths linking ordered pairs of nodes. Considering the diameter is a worst-case scenario.
- *Compactness* is given by the average length of the shortest paths between two nodes of the graph.
- *Complexity* is given by the ratio of edges to nodes of a graph.
- *Linearity* is given by the number of cycles and the lengths of the longest cycle.

A priori criteria must also account for the user's assessment efforts (Feldmann & Wagner, 2003):

- *Out-degree* is given by the number of edges leaving a node.
- *Cumulative number* is the number of links that have been evaluated while traversing hypermedia.

Table 2 provides an overview of both users' movement and users' assessment efforts. Here k is the number of nodes connected in the graph. For simplification, the out-degree \bar{a} is assumed to be constant. The movement efforts are expressed by means of an interval [minimal diameter, maximal diameter] as a function of the parameters \bar{a} and n to provide results that are valid for general types of graphs, rather than particular instances. The diameter is expressed using a mapping [] to the largest integer that is less than, or equal to, the argument a . A perfectly balanced tree with a constant out-degree minimizes the diameter. In contrast, the sequence with its out-degree equal to 1 maximizes the diameter. In the hierarchical structures, the nodes with no predecessor nodes are the entry nodes. Since the multi-tree consists of overlapping trees, it might have $b > 1$ entry nodes. In the net, every node can be an entry node.

In a sequence, the user may have to traverse all the links of the sequence to reach the node with the content of interest. If a tree and a sequence comprise an equal number of links, obviously the navigational effort differs significantly between the two topologies. In the sequence, the user does not have to make any assessments, but in a tree the alternatives have to be evaluated. However, the search path can be substantially abridged in a tree. This feature provides web designers with facilities for adapting the structure of hypermedia to the cultural preferences of the intended users prior to the implementation phase.

Table 2. Comparison of graph topologies with respect to the navigational efforts (adapted from Feldmann & Wagner, 2003, p.11)

Topology	Sequence	Tree	Multi-tree	Net
Characteristic	Succession	Hierarchy	Multiple hierarchies	Connectivity
Example				
(maximal) complexity	$\frac{n-1}{n}$	$\frac{n-1}{n}$	$\frac{n^2 - n \pmod{2}}{4n}$	$\frac{(n-1)}{2}$
Diameter d	$n - 1$	$\lceil \log_{\bar{a}}(n) \rceil; (n-1)$	$\lceil \log_{\bar{a}}\left(\frac{1}{b}(n+u)\right) \rceil; (n-1)$	$[1; n-1]$
(maximal) number of links to be assessed	0	$d\bar{a}$	$d\bar{a}$	$n-1$

Legend:

nodes; n number of nodes; \rightarrow directed link; $-$ undirected link;
 b number of entry nodes; \bar{a} out-degree; u number of shared nodes in a multi-tree.

Multi-Trees

Multi-trees address the differences of the navigational efforts outlined above by following two principles.

Hierarchical Order

The length of the path to reach a node is reduced by increasing the out-degree, \bar{a} . Consequently, the depth of a tree or a multi-tree decreases. Starting from a net structure with full connectivity, the assessment effort can be reduced by hierarchical ordering. The alleviation of assessment efforts is given by $e = k - \lceil \log_{\bar{a}}(k) \rceil \bar{a} - 1$. Thus, we can appraise changes of the structure ahead of the implementation. Feldmann and Wagner (2003) consider, for instance, $n = 500$ objects. A binary tree, ($\bar{a} = 2$), has a depth of $t = 8$. The user has to choose eight times between two alternatives and, therefore, must make six

assessments. The alleviation of assessment efforts is $e = 483$. A net with full connectivity embracing 500 nodes has $n(n-1)/2 = 124,750$ edges and maximizes the complexity to 249.5. A multi-tree with 500 nodes has a maximal complexity equal to 125 because of its hierarchical order.

Hiding Irrelevant Nodes

In a tree, a user has access to all the nodes, regardless of his or her particular interests. If the constant out-degree is $\bar{a} = 2$ and two entry nodes are available (as sketched in the example in Table 2), and the overlapping is on the second level of the hierarchy, the multi-tree consists of three branches. Nodes of the left branch are accessible only from the left entry node and nodes of the right branch are accessible only from the right entry node, but nodes of the middle branch are accessible from both entry

nodes. Extending this structure to Feldmann and Wagner's numerical example leads to 166 nodes in each of the branches. Because one of the three branches is hidden from the user, the complexity reduces to 0.664, but the diameter still equals 8.

An additional advantage of the multi-tree is the ability to cope with the diamonds in the graph structure (Furnas & Zacks, 1994). A diamond is a feature of a directed graph with at least two distinct paths from a node to a succeeding node, and such structures are frequently desirable. For instance, one path might allow the user to browse the website of an organization with respect to its divisions and subdivisions to find the contact details of a given person. However, browsing with respect to sites and locations might be a promising strategy as well, especially if the user knows the city in which the person is working. This browsing can be enabled by structuring with multi-trees, but not with alternative structures such as hyperbolic trees (Ontrup, Ritter, Scholz & Wagner 2009).

CONCLUSION

This study consists of two parts. In the first part, we empirically investigate the relevance of companies' cultural adaptation of their webpage. In contrast to previous HCI studies, we evaluate neither the users' behavior nor their preferences, but instead work out a contemporary state-of-practice by evaluating 215 webpages. Our research hypotheses are distinguished into two categories: those relating to the design aspects in terms of the use of references and colors on the one hand and those relating to the navigational aspects on the other hand. In contrast to previous HCI studies, which usually focus on the user's preferences and behavior, we found the design aspects to be less relevant for practitioners. This finding is in line with the common claim that in practice, companies' webpages are insufficiently culturally adapted, leading to the observation that "web site globalization has a long way to go" (Singh & Pereira, 2005, p. 16).

Notably, the two research hypotheses relating to the hypermedia's navigational aspects are not rejected for the data at hand.

Our results pinpoint the need for a simple but efficient tool for adapting webpages. Starting from a basic discussion of a graph-based structuring of hypermedia, we outline navigational (dis)advantages of tree and net structures. A numerical example shows that the multi-tree structure facilitates both cultural adaptation and efficient user navigation at minimal maintenance costs.

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APPENDIX

List of companies included in the study:

- ACER
- Adidas
- American Express
- Apple
- ASUS
- AXA
- BMW
- Bosch
- Brother
- Canon
- Chevrolet
- Coca Cola
- Deutsche Bank
- Epson
- Ford
- Fujifilm
- Hewlett-Packard
- Honda Motors
- Hyundai Motors
- IBM
- Intel
- JVC
- Lexmark
- LG
- McDonalds1
- Mercedes
- Microsoft
- Nestle
- Nike
- Nissan
- Nokia
- Oil of Olay
- Pampers
- Panasonic
- Rover
- Samsung Electronic
- Siemens
- Sony Ericsson
- Toshiba
- Toyota
- Volvo
- Whirlpool
- Xerox