

Navigability Design and Measurement

Hong Zhu

Oxford Brookes University, UK

Yanlong Zhang

Manchester Metropolitan University, UK

INTRODUCTION

Navigation has been a significant issue in portal design and evaluation because one of the biggest problems in using the Web is “lost in the information ocean.” To solve navigability problems in the development of Web sites in general, and portals in particular, navigation design guidelines and navigability metrics have been proposed and investigated in the literature. The guidelines are rules for the design of portal’s structures to ensure acceptable navigability. The metrics provide a set of quantitative measurements to analyse and evaluate the designs of portals so that the navigability can be judged objectively and compared precisely. These two approaches are complementary to each other, and form a set of Web engineering techniques to solve Web portal navigability problem.

THE NOTION OF NAVIGABILITY

Navigation comes from two Latin words: *navis* (ship) and *agrire* (to drive). According to the *Merriam-Webster Dictionary*, the general meaning of “navigation” is “to steer a course through a medium, to get around, move, to make one’s way over or through and to operate or control the course of.” The main purposes of navigation therefore are:

- figuring out where you are and
- moving from one place to another.

Therefore, navigation is the action or process of determining the position and directing the course to be travelled through a given environment (Darken & Siebert, 1993). In the environment of a portal or a Web site, navigation is the process through which the users achieve their purposes in using the portal or Web site, such as to find the information that they need or to complete the transactions that they want to do. As Nielsen (1999) pointed out, navigation design should help users answer three fundamental questions when browsing the site. They are “Where am I?” “Where have I been?”, and “Where should I go?”.

Based on this discussion, Zhang (2005) defined Web site navigability as *the ability enabled by Web-based systems*

to aid the users to locate themselves and move around the website easily for certain purposes, e.g. finding information, completing transactions, etc.

In the past a few years, Web site navigability has become a major concern of research as users become frustrated with poor designs. Web site navigation is a challenge because of the need to manage billions of information objects and to support users of vast different backgrounds.

Navigation Design

In the literature on Web navigation, several design guidelines have been proposed for navigation design; some are specific while others are heuristic (see, e.g., Fleming, 1998; Lowe & Hall, 1999). A widely quoted rule of navigation design is the “three-click rule,” which states that the user should be able to get from home page to any other page on the site within three clicks of the mouse. Some heuristics provide a rough guideline, such as “keep simple.” The following are among the most well-known navigability design guidelines:

- **Three Click Rule:** Every page of the Web site should be reachable from the homepage within a small number of clicks. Ideally, every page is reachable within three clicks.
- **Simple Structure Rule:** The linkage structure between the pages should be as simple as possible, for example, in hierarchy structure. That is, the main home page is linked to a number of subsites. Each subsite is linked to a number of sub-subsites, and so forth.
- **Error Recoverable Rule:** Every action that a user makes in the process of navigation should be recoverable by taking a recovery action, such as *undo* or *back*.
- **Minimize Memory Load:** The navigation process should require the user to remember as little as possible, for example, by providing indications of what the user has done and/or the position in the whole transaction process.
- **Explicit Rule:** The links to other pages should be made explicit and indicate the topic and key feature of the target page clearly so that the user can correctly expect where the link leads to.

MEASUREMENT OF NAVIGABILITY

It is widely recognised that measurement is central to all engineering disciplines. It is also true for Web site engineering. In the past 3 decades, significant progress has been made in the area of software measurement (see, e.g., Fenton & Pfleeger, 1997; Shepperd, 1995). Measurement is usually expressed in terms of metrics. A large number of software metrics have been proposed, investigated, and used in software development practices. The principles of measurement and metrics are studied in the mathematical theory of measurement and applied to software metrics, including Web metrics in general and Web navigability metrics in particular. A survey of Web metrics can be found in Dhyani and Bhowmick (2002).

As an abstract and subjective concept, Web site navigability is difficult to measure directly. Fortunately, Barfield (2004) and Spool, Scanlon, Schroeder, Snyder, and deAngelo's (1999) research results suggested a strong correlation between portal's structural complexity and its navigability. Thus, navigability can be measured objectively to a large extent by metrics define on the structure complexity of the portal.

Definitions of the Metrics

The measurement of Web sites' structural complexity used graph models in which a node represents a Web page and an edge a link between the pages. The following are some typical Web site structural complexity metrics (WSC).

- **Outgoing Links:** the number of outgoing links of a Web page indicates how easy it is to get lost, since each outgoing link represents a choice for the next step in navigation. The following metric is defined as the total number of outgoing links within a Web site.

$$WSC_1: OutLinks(W) = \sum_{n \in Node(W)} Out(n)$$

where W is the Web site to be measured, $Node(W)$ is the set of nodes, that is, the pages, of the Web site W , $Out(n)$ is the number of different Web pages that the node n links to. The metric *Outgoing Links* catches the intuition that a small Web site, with fewer pages and links, is less complex than a large Web site that has hundreds even thousands of pages and links. However, for comparison purposes, it is desirable to know its relative complexity taking size into consideration. Thus, we have the following metrics of average number of out links.

$$WSC_2: AverageOutLinks(W) = \frac{OutLinks(W)}{\|Node(W)\|}.$$

- **Number of Independent Paths:** One may argue that whether it is easy to find information in a Web site or become lost depends on the paths between the pages, not just the number of links on each page. By representing each path in a graph as a vector where the dimensions are the set of links, the paths in a graph form as a vector space. The linear dependence relation can be defined on the paths. A complexity metric of Web sites is defined as the number of independent paths in a hyperlinked network of Web pages. This led to the following metrics.

$$WSC_3: IndPaths(W) = \|Link(W)\| - \|Node(W)\| + 2\|EndNode(W)\|,$$

$$WSC_4: AverageIndPath(W) = \frac{IndPath(W)}{\|Node(W)\|},$$

where $Link(W)$ is the set of links between Web pages, $EndNode(W)$ is the set of end nodes, that is, it contains no links to other pages. The metrics assumed that every page on the Web site can be reached from the home page.

- **Fan Out:** The research on software measurement suggested that complexity increases with the square of connections (fan_{out}), where fan_{out} is number of the calls from a given module. In Web site designs, all pages are connected by hyperlinks. This leads to the following metrics for Web site structural complexity.

$$WSC_5: FanOut(W) = \sum_{n \in Node(W)} Out(n)^2$$

$$WSC_6: MeanFanOut(W) = \frac{FanOut(W)}{\|Node(W)\|}.$$

These metrics catch the intuition that not only does the number of links affect structural complexity, but also the distribution of the links within a Web site. Table 1 gives the complexity measures of four university portals denoted by U1 - U4 using the above metrics.

Validation of the Metrics

The metrics in Table 1 are formally verified against Weyuker's (1988) axioms of software complexity metrics, and validated on university portals through empirical studies of the correlation between the Web structural complexity and navigability.

Weyuker's axioms of software complexity, shown in Table 2, were proposed for measuring program complexity, where P and Q represent software systems, $P; Q$ is the

Table 1. Examples of structural complexities of university portals

Site	#Pages	WSC ₁	WSC ₂	WSC ₃	WSC ₄	WSC ₅
U1	5842	107493	18.4	103403	17.7	6215888
U2	6824	128974	18.9	124197	18.2	8257040
U3	3685	85861	23.3	82913	22.5	4543605
U4	4608	131789	28.6	128563	27.9	8451072

Table 2. Weyuker's axioms of software complexity metrics

Axiom	Definition
Axiom 1	There exist P and Q such that $M(P) \neq M(Q)$.
Axiom 2	If c is a nonnegative number, then there exist only finitely many P such that $M(P) = c$.
Axiom 3	There exist distinct P and Q such that $M(P) = M(Q)$.
Axiom 4	There exist functionally equivalent P and Q such that $M(P) \neq M(Q)$.
Axiom 5	For any P and Q , we have $M(P;Q) \geq M(P)$ and $M(P;Q) \neq M(Q)$.
Axiom 6	There exist P , Q and R such that $M(P) = M(Q)$ and $M(P;R) \neq M(Q;R)$.
Axiom 7	There exist P and Q such that Q is formed by permuting the order of the statements of P and $M(P) \neq M(Q)$.
Axiom 8	If P is a renaming of Q , then $M(P) = M(Q)$.
Axiom 9	There exist P and Q such that $M(P) + M(Q) < M(P;Q)$.

composition of two software systems, and M stands for a complexity metric.

Although portals are software systems, the representation of Weyuker's axioms must be adapted before they can be applied to study portal complexity metrics. Table 3 shows how each of the metrics defined satisfies the axioms in Table 2. Readers are referred to Zhang, Zhu, and Greenwood's (2004) research paper for the details of the adaptation of the axioms and formal proofs of the properties.

It can be seen from Table 1 that WSC₅ complies with the adapted Weyuker's axiom system completely; other metrics comply with most of the axioms. Considering that most successful software complexity metrics cannot satisfy all axioms, all WSC metrics are good candidates for Web site structural complexity measurement.

A user-centered questionnaire investigation was also conducted to compare users' view of navigability against the metrics of Web site structural complexity. In this study, the four university portals given in Table 1 were used. The results, shown in Table 4, clearly demonstrated that the relative complexity metrics matched users' subjective feelings on navigability very well.

CONCLUSION

Navigability is an important issue in the design of Web sites in general, and portals in particular. Both navigability design guidelines and evaluation metrics have been proposed and investigated in the literature. The metrics have the following advantages compared with design guidelines. First, they are easy to use. Automated tools can be developed to measure portal's complexity. The measurement of a complicated Web site's complexity can be performed within seconds or minutes. Second, they can be used to estimate the structural complexity and navigability during the early phase of the process, as well as in the evaluation of a portal objectively. For example, it was found that average WSC₂ of university portals is between 18 and 28. This can be used as an indicator to avoid over-complicated designs of university portals. Finally, it is worth noting that the metrics do not use any particular properties of the university portals, such as the structures and contents. Therefore, they should be equally applicable to other types of portals.

Table 3. Assessment of metrics against adapted Weyuker's axioms

Metrics Axiom \	WSC ₁	WSC ₂	WSC ₃	WSC ₄	WSC ₅	WSC ₆
Axiom 1	Yes	Yes	Yes	Yes	Yes	Yes
Axiom 2	Yes	No	No	No	Yes	No
Axiom 3	Yes	Yes	Yes	Yes	Yes	Yes
Axiom 4	Yes	Yes	Yes	Yes	Yes	Yes
Axiom 5	Yes	No	Yes	No	Yes	No
Axiom 6	No	Yes	Yes	Yes	Yes	Yes
Axiom 7	No	No	Yes	Yes	Yes	Yes
Axiom 8	Yes	Yes	Yes	Yes	Yes	Yes
Axiom 9	Yes	No	No	No	Yes	Yes

Table 4. Correlations between navigability and metrics

Metric	Correlation
WSC ₁	-0.452
WSC ₂	-0.908
WSC ₃	-0.479
WSC ₄	-0.909
WSC ₅	-0.479
WSC ₆	-0.945

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KEY TERMS

Error Recoverable Rule: A navigability design rule that suggests that in the design of a Web site or portal, every action that a user makes in the process of navigation should be recoverable by taking a recovery action, such as *undo* or *back*.

Explicit Rule: A navigability design rule that suggests that in the design of a Web site or portal, the links to other pages should be made explicit and indicate the topic and key feature of the target page clearly, so that the user can expect where the link leads to correctly.

Minimize Memory Load: A navigability design rule that suggests that in the design of a Web site or portal, the

navigation process should require the user to remember as little as possible, for example, by providing indications of what the user has done and/or the position in the whole transaction process.

Navigability: The ability enabled by Web-based systems to aid the users to locate themselves and move around the Web site easily for certain purposes, for example, finding information, completing transactions, and so forth.

Navigability Design Guidelines: Navigability design guidelines are instructive rules that guide the designers of Web sites and portals to achieve high navigability.

Navigability Measurement Metrics: A navigability measurement metrics is a well-defined mathematical formula that maps Web sites or portals to a numerical system that indicates the navigability of the Web sites/portals. Typical

example of such metrics are Web site complexity metrics, such as average out-going links from a page, the number of independent paths in a Web site, the average fan outs of a Web site, and so forth.

Simple Structure Rule: A navigability design rule that suggests that in the design of a Web site or portal, the linkage structure between the pages should be as simple as possible, for example, in hierarchy structure. That is, the main home page is linked to a number of subsites. Each subsite is linked to a number of sub-subsites, and so forth.

Three Click Rule: A navigability design rule that suggests that in the design of a Web site or portal, every page of the Web site should be reachable from the home page within a small number of clicks. Ideally, every page is reachable within three clicks.