WWW Site Design for Internal and External Audiences: The Smart Engineering Project

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Abstract

The Smart Engineering project seeks to develop a model for training engineers with interdisciplinary skills and experiences. It involves an interdisciplinary course and a demonstration highway bridge. An associated WWW site provides course resources including tutorials in topical areas, exercises promoting team interaction, and guidance for collaborative activities and bridge documentation which facilitates industry access to current research and field applications in smart structures. It must accommodate a well-defined internal student audience and a general external industry audience. The site objectives are to effectively inform both audiences and to exploit the capabilities of the WWW. The design philosophy stresses the close interaction of content providers with media programmers and the careful consideration of audience characteristics. It follows comprehensive guidelines for modularity, circularity, and commonality and balances contrasting goals of simplicity and complexity. The former concerns the site hierarchy, usage, and navigation. The latter concerns usability verses interactivity and consistency verses adaptability.

I. Introduction

The World Wide Web, or the WWW, provides an exciting alternative to traditional forms of media. Vast amounts of information are readily accessible and may be available in a highly interactive form. An effective WWW site will address the fundamentals of communication in the context of the varied capabilities and characteristics of current WWW technology. WWW educational resources can easily incorporate interactivity and multimedia. Research indicates that learning can be better when the learner is actively engaged, as opposed to passive reading or listening,[1] and that student interest and motivation can be increased using dynamic multimedia.[2] A clear design philosophy is needed which stresses the close interaction of content providers with media programmers and the careful consideration of the audience characteristics. Content providers and programmers cannot work independently. Otherwise, subtleties and priorities in the content can be missed, and the technology may be poorly applied or inadequately utilized. Audience analysis should guide all design steps since no amount of creativity or capability can substitute for intelligent tailoring of the WWW experience. A systematic and holistic approach will help ensure that all site components contribute to the learning or information goals.

An audience may be classified as either internal or external. An internal audience consists of users within the organization for whom the WWW site is being created. An external audience is interested individuals outside of the organization. The versatility of the WWW is such that all of these audiences, both internal and external, can be effectively addressed with a single site. These users will differ in their WWW experience, preferences, hardware, motivation, and information needs. In particular, experience using WWW resources has been identified as a key factor in learning effectiveness.[3-5] Other factors include learning styles,[6-8] thinking styles,[9] and multiple intelligences.[10,11] The user's hardware is the filter through which the content is seen.[12] As for more traditional media like print, television, and speech, the target audience and communication purposes should be clearly understood.[13] However, there are differences. Simply transferring the classroom lecture to the computer screen as a talking head may be less effective than the original lecture.[14]

In this paper, we describe the *Smart Engineering* WWW site[15] which provides resources for an interdisciplinary course and related project documentation on a demonstration highway bridge. The site, the course, and the bridge are part of a Combined Research Curriculum Development project from the National Science Foundation. The objectives are the development of interdisciplinary skills and knowledge and the transfer of new technology to application. The course is "Smart Materials and Sensors" and is co-listed in electrical, civil, aerospace, and mechanical engineering. It emphasizes the interconnectedness of knowledge in the smart structures area. The bridge is a field laboratory for students and a long-term demonstration for industry. The WWW site serves both an internal audience of students and an external audience of industry.

The site has a clear design philosophy.[16] The site content for the course and the bridge are closely linked and must accommodate the well-defined internal student audience and the general external industry audience. The objectives are to provide current information effectively for both audiences and to exploit the capabilities of the WWW multimedia. This paper will show how the site design incorporates comprehensive guidelines for modularity, circularity, and commonality and how it balances contrasting goals of simplicity and complexity. The former concerns the site hierarchy, usage, and navigation. The latter concerns usability verses interactivity and consistency verses adaptability.

II. The Smart Engineering Project

This curriculum development project seeks to develop a model for training engineers with interdisciplinary skills and experiences and to promote the transfer of new technology to application. The technical area of interest is smart structures which cross traditional boundaries by combining materials, manufacturing, sensing, signal processing, structural analysis, etc. The application of this and other new technologies are often limited by the ability of engineers to work in interdisciplinary teams. However, most engineers are educated with little interdisciplinary experience. Consequently, they may lack a needed understanding of the discipline-specific terminology and connecting concepts. For instance, a load test on a new bridge element could involve civil, electrical, manufacturing, and mechanics engineers. The civil engineer needs an appreciation for sensor noise and processing accuracy; the electrical engineer needs to be aware of strain directions and bonding issues; etc.

The project includes a senior-elective/introductory-graduate level course and a demonstration smart bridge. The associated WWW site is the focal environment for student learning and an industry resource for technology evaluation. The course was taught during the Fall semester of 1999 with fourteen students and during the Fall semester of 2000 with fifteen students. All co-listed disciplines were represented. Course activities are divided among out-of-class tutorial instruction, in-class Socratic lectures, and team assignments including homework problems, demonstration laboratories, and analytical projects. Web-based course resources include tutorials in topical areas, exercises promoting team interaction, and guidance for collaborative activities. Web-based asynchronous instruction is used mainly to tailor content for individual student backgrounds so that the in-class activities can focus on integrating knowledge and collaboration. Although the primary student audience is internal, the resources also provide overviews in the topical areas for the external industry. The bridge was designed, manufactured, and tested for highway loads. It features all-composite construction and integral fiber-optic sensors. Web-based documentation facilitates industry access to current research and field applications in smart structures. It is a long-term demonstration of advanced technology for industry (the external audience) and is a field laboratory for students (the internal audience).

The analyses of the internal and external audiences show considerable differences. The internal audience of students is well defined. They have considerable experience with web-based navigation and have access to high performance hardware. Their usage of the site largely follows prescribed assignments. Their motivation and interest in the site material is high due to course requirements and their selection of the elective course. Their main differences are in personality, cultural background, preferences,[7] and discipline, all of which are well delineated by transcript, instructor observation, and course surveys. The external industry audience is less defined. Experience, hardware, and usage will vary widely. They will generally be seeking answers to specific questions rather than comprehensive knowledge. Their needs and preferences will have to be anticipated rather than directly measured. The WWW is a useful information vehicle for these target audiences in terms of timeliness, flexibility, and interconnectedness. A single site update is instantly available to all users, giving both audiences timely information. The site must be flexible enough to accommodate the differing needs and usage patterns. Beyond general user friendliness, the site should provide students with interactive learning aids and industry users with ready access to progressive levels of detail. Furthermore, the WWW demonstrates the interconnectedness of the topical knowledge through the use of hypertext links and a hypermap structure.

III. WWW Site Overview

Usage of a WWW site is characterized by the hypermedia experience of the user with both the WWW in general and the specific site. Novice users may become easily disoriented without clear guidance and consistency, while experienced users may desire a more complex navigational design.[3,17] On the other hand, some complexity such as encouragement of an interactive user-defined access order may be directed at either user. Instructional goals will determine when complexity is needed. A well-structured site should demonstrate (1) modularity, (2) circularity, and (3) commonality.[12] Simple and complex navigation are facilitated by the structural hierarchy shown in Figure 1. The site is modular consisting of a small number of collections which, in turn, contain sets of pages. This structuring method helps define a general default flow through the content, even if it is not used, and gives the user a context to view the information. In addition, the site should exhibit circularity, i.e., there are no dead ends. After a particular default path has been completed, the user should be directed to a page that has links to equivalent levels of information. A default path should not limit hyperlinks permitting alternatives such as parallel or intertwining intrasite paths and intersite site links. The site should have commonality in which the same general format and similar menu options are given on all or most pages. The user should immediately know when he has left the site, and he should be able to directly access any collection element in the site.

The *Smart Engineering* site is illustrated in Figure 2. It consists of a gateway page summarizing the project and the content of the site. The content is divided into five collections: smart bridge, “Smart Materials and Sensors” course, “Smart Civil Structures” course, personnel, and site index. (The “Smart Civil Structures” course site is undeveloped and will not be discussed further.) The modular structure aids navigation for the user and revision for the developers. Each collection has a default path for circularity. This path gives clear alternatives for those users who have reached the level of detail desired. All pages have a similar background and menu location. In particular, a two-level menu is used in all pages within the collections. A smart bridge page is shown as an example in Figure 3. The upper menu shows all of the collections in the site and

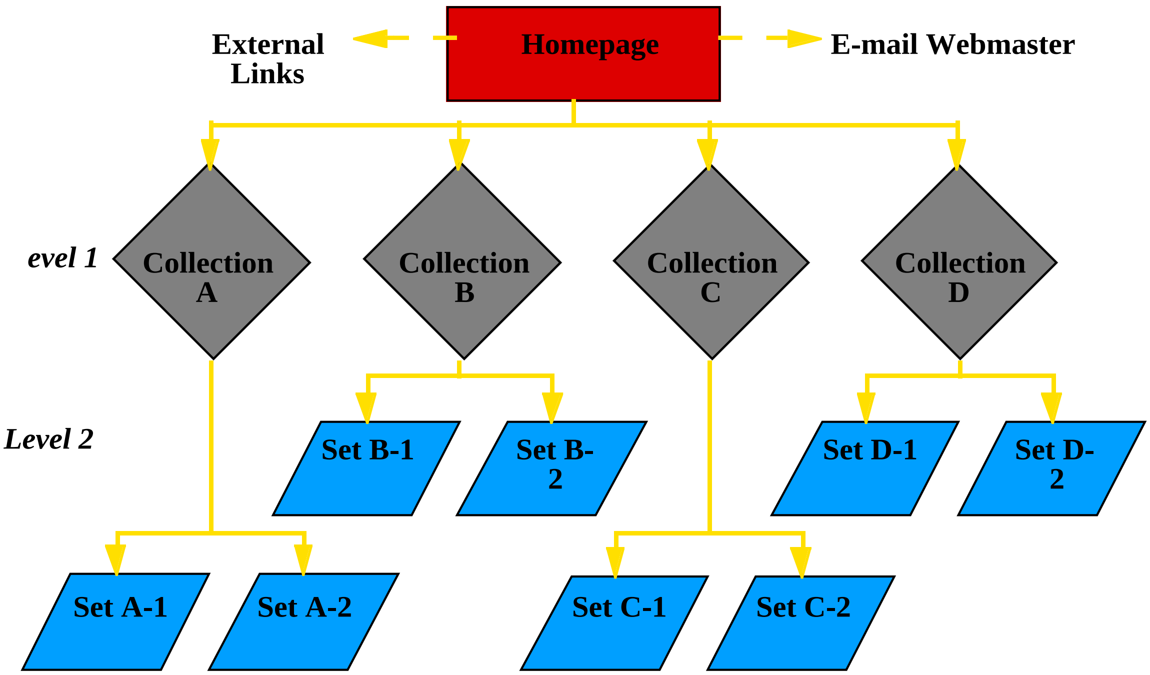

Figure 1: Modular hierarchy of a web site. Intrasite and intersite hyperlinks are not shown. The common menu includes hyperlinks to level 1 sites and return links to parent pages.

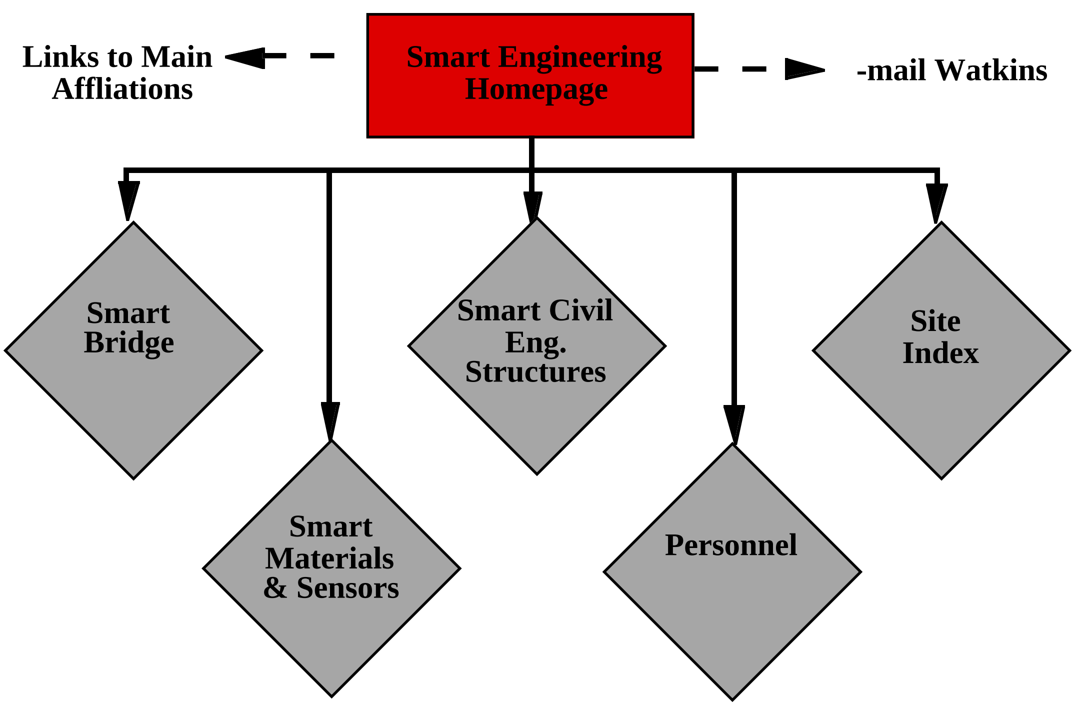

Figure 2: Structure of the *Smart Engineering* site.

indicates with an asterisk the active collection "Smart Bridge." The lower menu shows each set in the collection and indicates with an asterisk the active set "Bridge Index." Note that this collection index is available in addition to the site index. Common links are also provided at the bottom of the page to the university site, the National Science Foundation site, and the webmaster E-mail.

Key aspects of both the course content and the bridge documentation are the availability of progressive levels of detail. The student users differ greatly in their technical background within the different disciplines. The first half semester for the course deals with foundational material in each

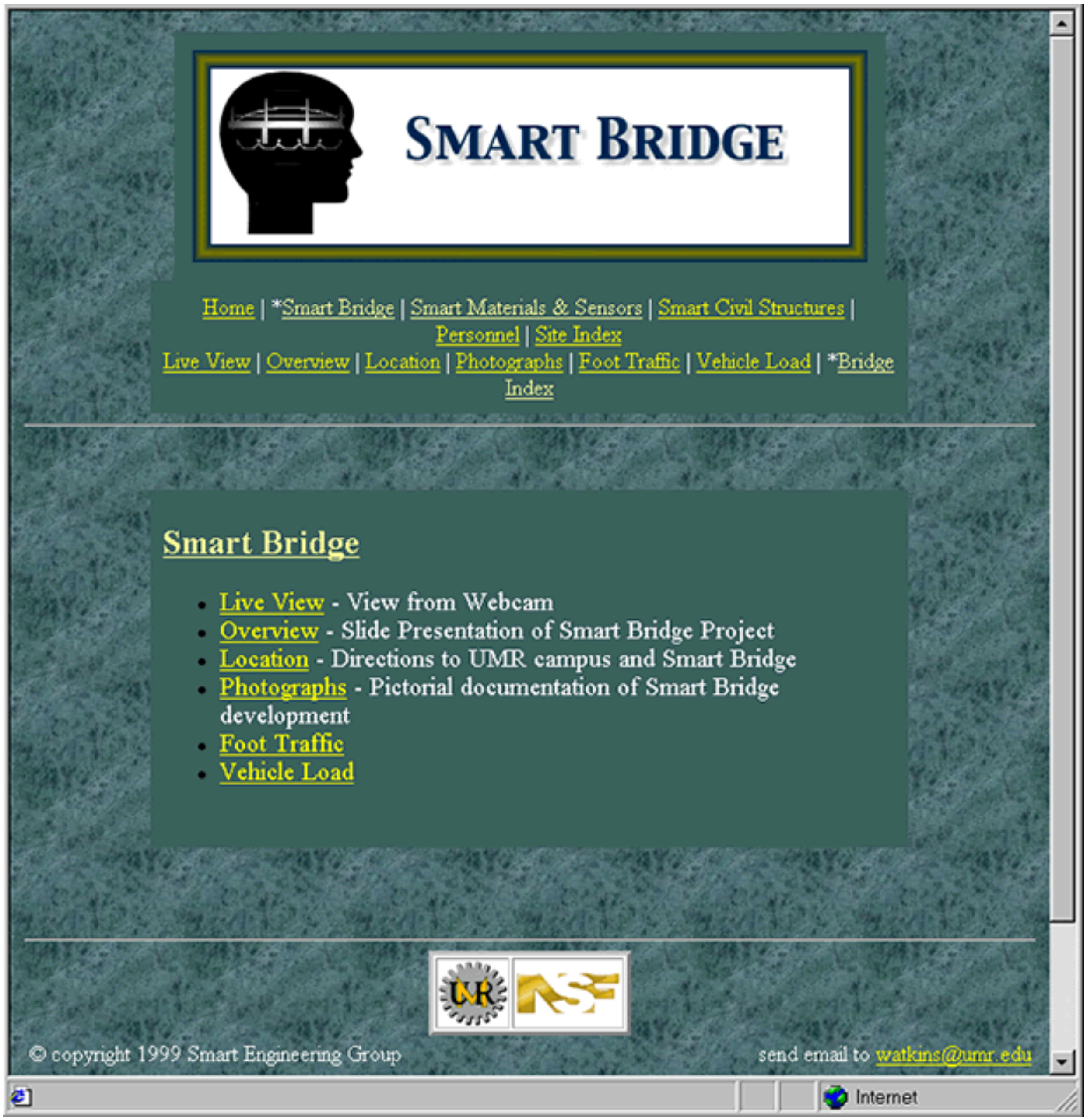

Figure 3: Page in "Smart Bridge" collection showing the set "Bridge Index."

of the component disciplines. Web tutorials are provided, and their completion is required before attending the weekly Socratic lecture. This procedure allowed all students to have a working knowledge before the lecture so that a higher level discussion would be possible. Students working in their major would need a brief review of the tutorials while students working out of their major would need to study the tutorials in depth. Industry users of the site are expected to have questions ranging from general capabilities of the project technologies to specific aspects of the bridge application. Each set in the "Smart Bridge" collection emphasizes a different level and type of information. For instance, the "Overview" set will have an overview presentation as well as electronic copies of documentation papers and the "Photographs" set has pictorial documentation of the bridge development.

IV. WWW Site Design

Once the main structure and page templates are developed, the detailed design begins. The process may be viewed as a balance of simplicity and complexity as illustrated in Figure 4. Users have conflicting needs for consistent and usable content that is succinct, easy to navigate, and efficiently downloaded and for interactive and adaptable features that provide a rich and creative learning environment. Much of the literature on WWW design stresses simplicity. For instance, researchers in instructional web design have recommended that

- Text presented on a given page should be limited,[18,19]
- Scrolling should be avoided,[20] and
- Graphics and multimedia should be used only for clear instructional purpose.[18,21]

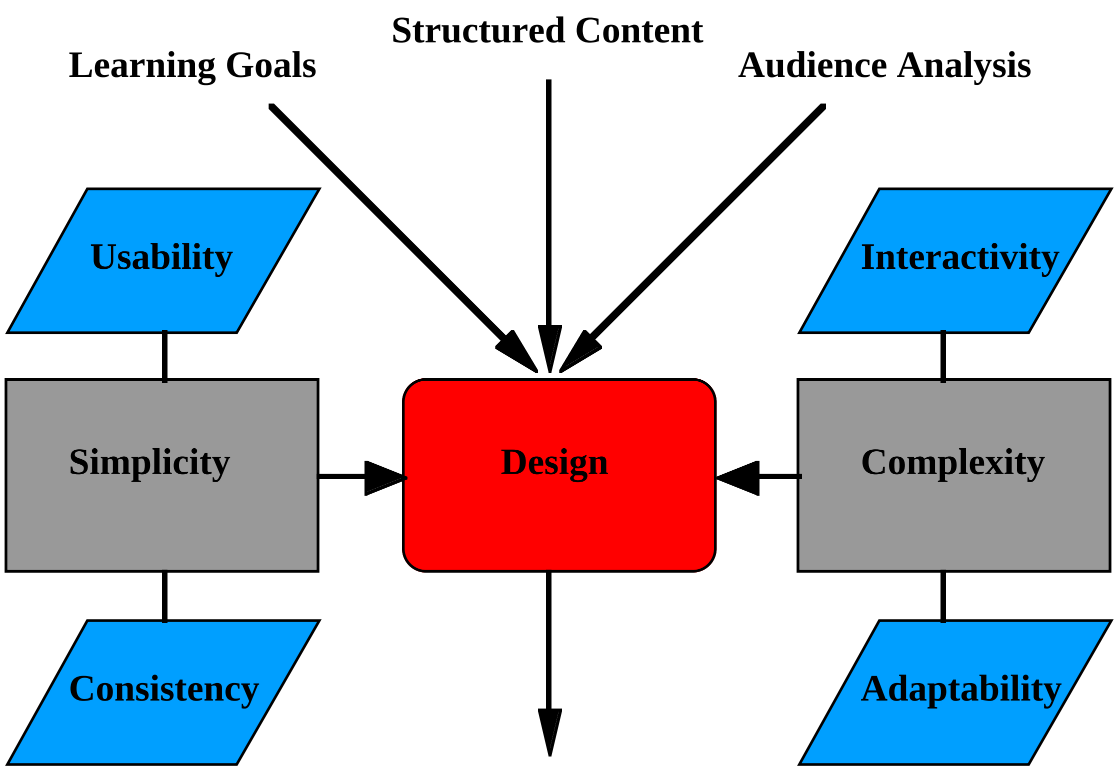

Figure 4: Design Model for Effective Learning

Design incorporating simplicity is most appropriate during the initial exposure of an audience to the site and when the audience is seeking specific facts or instructions. However, there is a definite role for complexity. Elaborate demonstrations, simulations, and multimedia can enhance learning and stimulate interest in content.[2] This recommendation is consistent with cognitive flexibility theory.[22] Design with complexity is most appropriate with more experienced users and when the audience must integrate knowledge.

The project WWW site has a mixture of simplicity and complexity elements. The site homepage and the main pages for each collection are mainly text and have limited content. A user's initial exposure to the site is highly usable with clear guidance on the site content. For the student audience, administrative and reference information such as the course syllabus and policies is free of graphical clutter and interactive elements. For the industry audience, the bridge collection has succinct sets for the location, overview, foot traffic, and vehicle loading (see menu in Figure 3). The typical industry user is anticipated to have a desire to obtain information simply and quickly. However, for both audience groups, there is more complex content. The course tutorials contain a variety of graphics, and on-line features such as self-quizzes and simulations are planned. Intrasite links are highlighted, in particular to the bridge documentation, to encourage user exploration. The bridge collection includes a live view from a web camera to stimulate interest and photograph gallery of the bridge development. The photograph gallery is an example of progressive complexity in which the audience may chose to use increasing detailed pages if desired. The user initially views thumbnail photographs with the option to view higher quality images.

A tutorial page is shown in Figure 5. A frames template was chosen to provide for user preferences. The left-hand frame contains the tutorial text. The right-hand frame contains graphics that are linked from the text. User may read the text and view the graphics as they see fit. Prior research has shown that a learning-styles preference between rich graphics and minimal graphics can affect audience satisfaction and performance.[7] Embedded graphics were found to decrease learning effectiveness for some students. The graphics supplement the text, but are not required for full understanding.

V. Summary

The *Smart Engineering* WWW site provides resources in information and education for an internal student audience and an external industry audience. While acknowledging the unique advantages and characteristics of the WWW, the role of audience awareness and analysis, as in traditional communication media, is emphasized. Its design philosophy incorporates principles of modularity, circularity, and commonality to provide users a context to view the site and to make navigation more intuitive whether the users followed the default path or an alternative path. The learning environment should reflect a thoughtful balance of simplicity and complexity. Gratuitous bells and whistles should be avoided, but relevant multimedia and interactivity should be included to take advantage of the unique strengths of the technology. This approach is based on the premise that content providers and WWW programmers must interact throughout the development process to truly meet the instructional goals of the site.

The WWW is a particularly useful vehicle for the effective delivery of complex, interdisciplinary knowledge. The technical content of the subject area can be viewed as forming a three-dimensional knowledge space linking materials, metrology and signal processing, and applications. The WWW site can graphically and relationally interconnect all of the course components and the technical topics. Hence, instructional methodology needs to emphasize the interconnectedness of the area, and the WWW site structure assists by mirroring this interconnectedness.

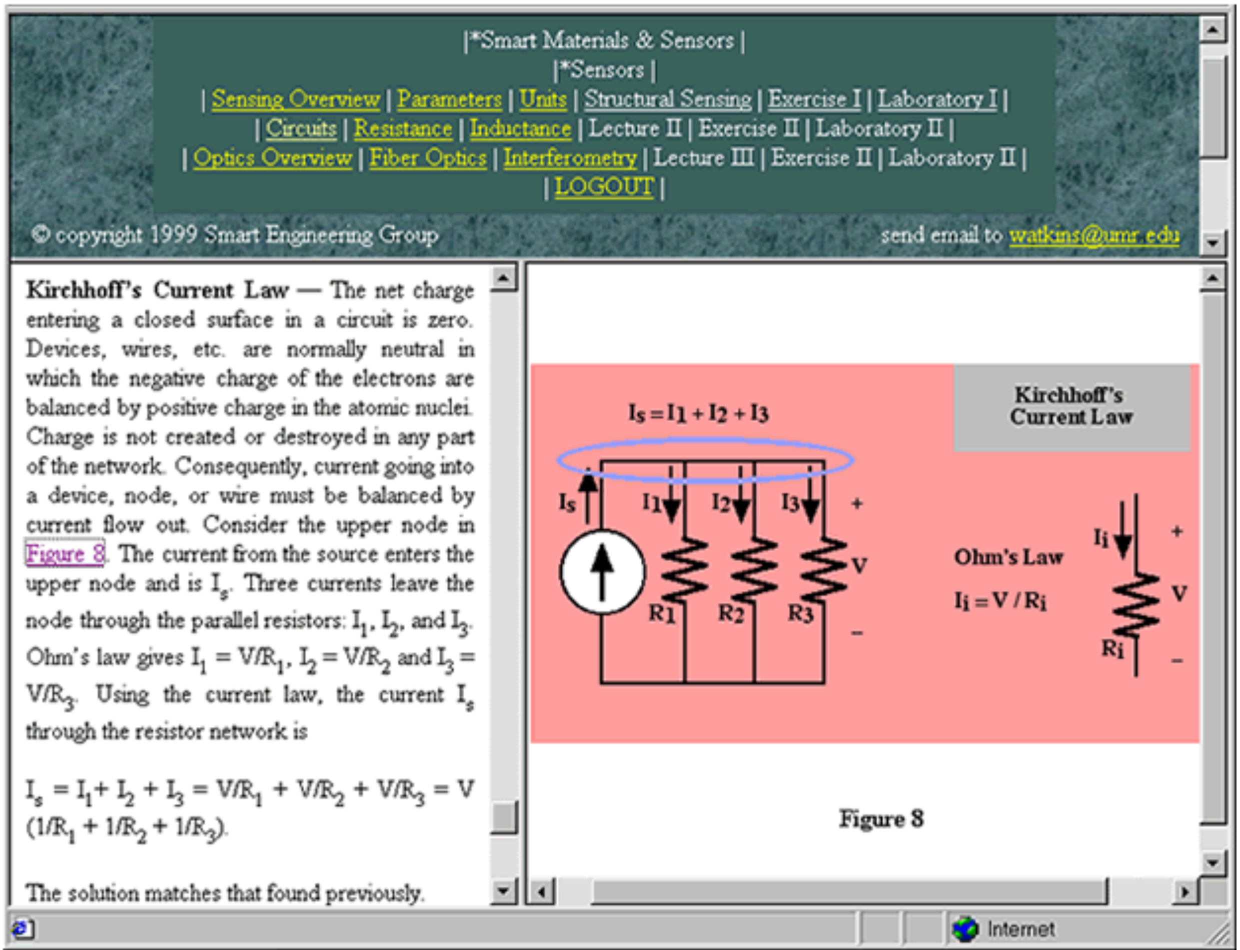

Figure 5: Page in the Sensing Tutorial for the Course.

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