
WWW instructional documentation for the development of a smart composite bridge

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Abstract: An instructional World-Wide-Web (WWW) site for a smart composite bridge provides technical documentation to a diverse audience including professional and student users. It describes a prototype bridge project that demonstrates the use of fibre-reinforced-composites and smart sensing techniques for civil engineering applications. This smart composite bridge is a long-term technological demonstration for industry and an interdisciplinary field laboratory for students. The site content includes live images, technical details, associated publications, manufacturing protocols and developmental testing. The site objectives are to provide current information, to organise progressive levels of detail and to exploit WWW instructional capabilities. Clear organisation, navigational aids, supplementary helps and content layering balances the user needs (1) for simplicity through consistent presentation and usability and (2) for complexity through user-centred options and multimedia. This instructional tool models effective communication of research to industry and the classroom. It shows how site design can accommodate diverse needs of information delivery.

Keywords: Instructional technology; World-Wide-Web-based education; web design; technology transfer.

Reference to this paper should be made as follows: Watkins, S.E., Eller, V.M. and Hall, R.H. (2003) 'WWW instructional documentation for the development of a smart composite bridge', *Int. J. Continuing Engineering Education and Lifelong Learning*, Vol. 13, Nos. 1/2, pp.180-189.

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1 Introduction

The World Wide Web (WWW) opens new instructional possibilities for communicating technological innovations to working professionals and student engineers [1]. The media is highly flexible and is readily accessible. Its versatility is such that diverse users can be addressed in a single site, but effective use of this media requires user-centred organisation and design. Simply transferring a traditional classroom teaching model and linking traditional documents or video does not use the full capabilities of the WWW. Technical content, educational design and programming resources must be integrated. Instructional goals and audience analysis should be considered in the context of specific design guidelines.

In this paper, we describe the 'Smart Composite Bridge' component of the *Smart Engineering* WWW site [2] which provides comprehensive documentation on a demonstration highway bridge. The prototype bridge, the first fully-composite bridge in Missouri, was designed for highway loading, although its normal usage on the University of Missouri-Rolla (UMR) campus is by pedestrians and light vehicles. It was designed, analysed and manufactured as a cooperative product development and technologies demonstration among university, industry and government partners. The associated

WWW site presents an intelligently-tailored instructional environment with imagery from a live web-camera, technical information and papers, the location of the bridge, a photographic record of development and descriptions of load tests. The site is the primary documentation for the bridge project and is intended as an environment for instruction and demonstration of new technologies. It serves both external professional users and internal student users. Its usage objectives are to provide current information, to organise progressive levels of detail and to exploit WWW instructional capabilities.

2 The smart composite bridge project

2.1 Project overview

The smart composite bridge is a short-span structure that incorporates advanced materials and smart sensing technologies that can be applied to other civil engineering structures. In particular, it has a fibre-reinforced-polymer composite design exceeding an AASHTO H20 highway rating [3] and an integral sensor network for in-situ health monitoring capability [4,5]. The project engineering was done by an interdisciplinary team of UMR faculty, the manufacturing partner was Composite Products Inc., and the funding sources were a variety of public and private organisations (see acknowledgements). The work leading to this prototype included iterative design using finite element modelling, full-scale laboratory testing to validate strength and fatigue performance [6], protocols for manufacturing, assembly and installation and cost analysis [7] for commercialising the technologies. The bridge is a long-term technological demonstration for industry and an interdisciplinary field laboratory for UMR students.

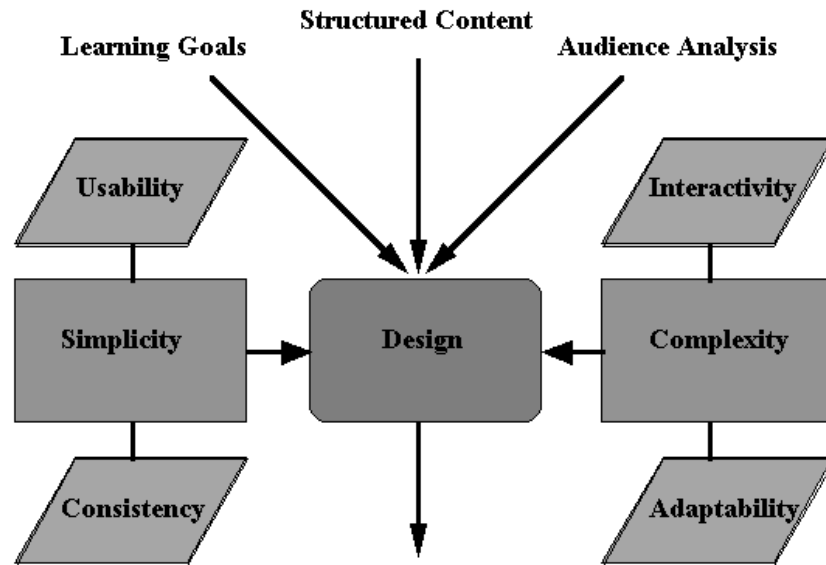
The project addresses the need for improvement in bridge technologies. The USA's bridge infrastructure is rapidly aging and many bridges will need to be replaced or repaired in the near future [7]. Fibre-reinforced-polymer composite materials have weight, service life and handling advantages over traditional construction materials for applications including new construction of short-span bridges, bridge decks, etc. and repair or rehabilitation of existing reinforced-concrete bridges. Smart structures techniques, especially those involving fibre optics sensors, can provide structural information that is otherwise too difficult or expensive to obtain. To effectively transfer the technologies to general application from the research arena, working engineers and students must have current information on implementation issues, proven protocols and representative field demonstrations. For instance, correlation between the finite element simulation results and the actual performance during the load test shown in Figure 1 can promote confidence in the maturity of materials and sensing technologies. WWW documentation of a field demonstration is especially valuable from a technology transfer perspective due to its general availability and comprehensiveness.

Figure 1 Load test of the UMR smart composite bridge

2.2 WWW documentation

The associated WWW site [2] documents the bridge project in a user-centred and readily accessible format. It is a communication vehicle for the transfer of research results and field demonstrations to engineers and students who can apply the technologies. It must simultaneously accommodate all users despite the wide range of interests and backgrounds [8]. Working engineers are expected to have questions ranging from general capabilities of the project technologies to specific aspects of the bridge development. The site provides an up-to-date reference and will be a resource for planned industrial short courses. On-campus students use the site content in an associated interdisciplinary course 'Smart Materials and Sensors' [9]. The bridge development is a case study for lecture and the instrumented bridge is a laboratory facility. For both types of users, the site is the primary repository for both general and detailed information for all phases of a prototype project. The WWW format features a rich environment of text, imagery and hyperlinks. The bridge documentation is a companion WWW component to the course WWW resources. An interactive LabView simulation of the bridge load tests is under development and will be available on the course site [10].

The site has a clear design philosophy as shown in Figure 2 [11]. Design elements flow from the content, learning goals and intended audience. Effective integration of these considerations necessitates close cooperation among content providers, instructional experts and WWW programmers. The content includes documentation of the bridge project and its component technologies. The learning goals include reference and tutorial functions. The intended learners or users are working engineers and students.

Figure 2 Design philosophy for the WWW learning environment

The design integrates contrasting usage elements of simplicity and complexity. Design choices must balance usability versus interactivity and consistency versus adaptability. Gratuitous bells and whistles are avoided, but relevant detail, media and interactivity are presented as user-selected options. Simplicity provides succinct content, ease of navigation and efficient download performance, while complexity features provide rich, creative learning opportunities.

Supplemental WWW guidelines of modularity, circularity and commonality determine site hierarchy, usage and navigation. The site structure mirrors the interconnectedness of the content and the site navigation aids are intuitive whether users follow a default path or an alternative path. Modular organisation 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. Circularity eliminates dead ends. A user should be guided by explicit links or by the menu to connected sources of information. However, alternatives such as parallel or intertwining intrasite paths and intersite site links are incorporated. Commonality creates a purposeful environment. A general page format and common menu options identify the site boundaries of the site and allow direct access to main element in the site.

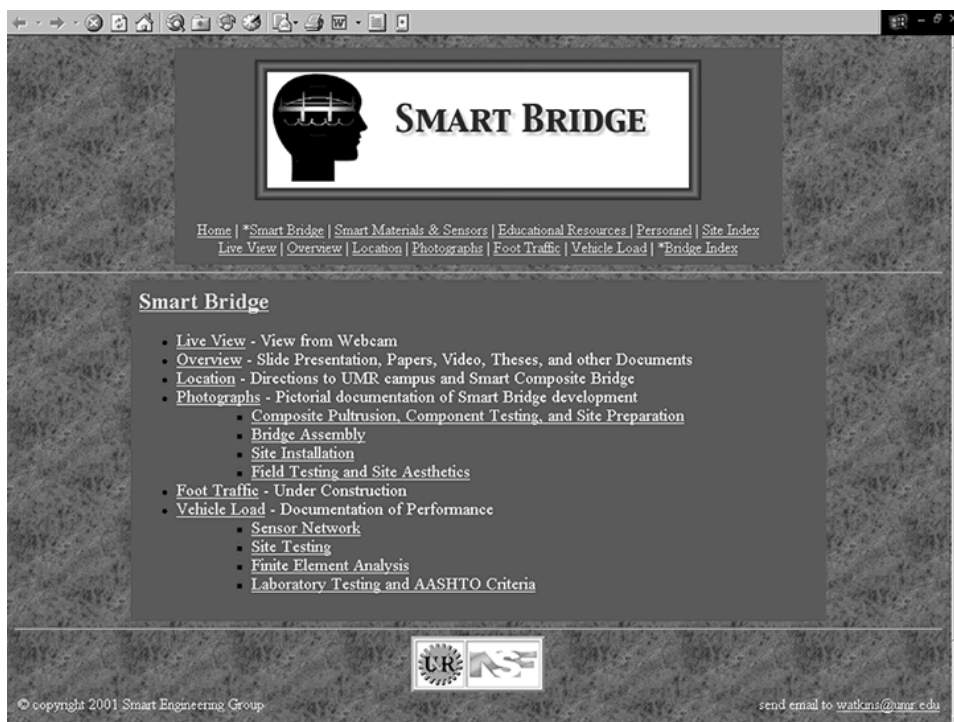
3 WWW site content and usage

3.1 Site content

The index page for the 'Smart Composite Bridge' site is shown in Figure 3. The top menu shows the modular collections in the *Smart Engineering* umbrella site that include a gateway 'Home' page for the sponsoring National Science Foundation project, the

bridge site, course site, educational resources, personnel information and a general index. The second menu shows the organisation of the bridge site and documentation into seven sets. The first page in each set, with the exception of the 'Live View' page, contains mainly text and limited content to promote rapid browsing. Subordinate pages are optional and contain progressive levels of detail, media and interactivity. All pages have a similar background and menu location. The index listings, the project director E-mail (lower right-hand corner) and the personnel section facilitate further investigation and communication.

Figure 3 Site page in 'smart bridge' collection showing the set 'bridge index'



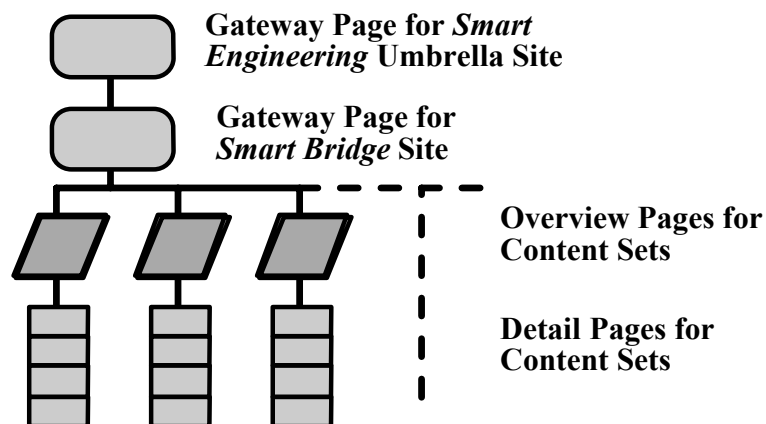
Each set of pages addresses an anticipated need of users. The 'Live View' page features a live view from a web-camera to stimulate interest and reinforce the practical nature of the project. The 'Overview' set contains an introductory slide presentation of the project; abstracts of thesis documents, journal papers and conference presentations; and pdf. downloads for full papers. A video presentation of the development, testing and installation is also in preparation. The 'Location' page gives the physical location of bridge. The 'Photographs' set contains a selection of images for the testing, manufacture and installation phases of the project. The 'Foot Traffic' and Vehicle Load' sets will contain the technical record of the bridge performance under load and will correlate field results with simulations, laboratory tests and design specifications. The organisational intent is to clearly divide content by expected usage, type and technical detail.

3.2 Progressive complexity

A key feature of the site is progressive complexity. Each user will approach the learning experience with different desires and interests. A first-time user may be inexperienced with WWW capability and may be unfamiliar with the technologies. An external industry user will have usage preferences and information needs that are varied. The typical industrial user may want to obtain specific information directly and quickly. An internal student user will have access to high performance computer hardware and connections. Also, a student user may need comprehensive understanding of the bridge project, but is probably familiar with the similar structure and layout of the course information. Layering the content balances the competing needs for simplicity through consistent presentation and ease of use and for complexity through varied options and multimedia. Design incorporating simplicity is most appropriate during the initial exposure of a user to the site and when the user is seeking specific facts or instructions. Design with complexity is most appropriate with more experienced users and when the user must integrate knowledge.

A modular structure is presented through the menu options that accommodates varied usage patterns. The documentation collection for the bridge and the other collections for the associated course, educational resources, personnel and general index provide immediate top-level menu choices for users to tailor their learning experience. The second-level menu separates content into well-defined sets. The modular structure is diagrammed in Figure 4.

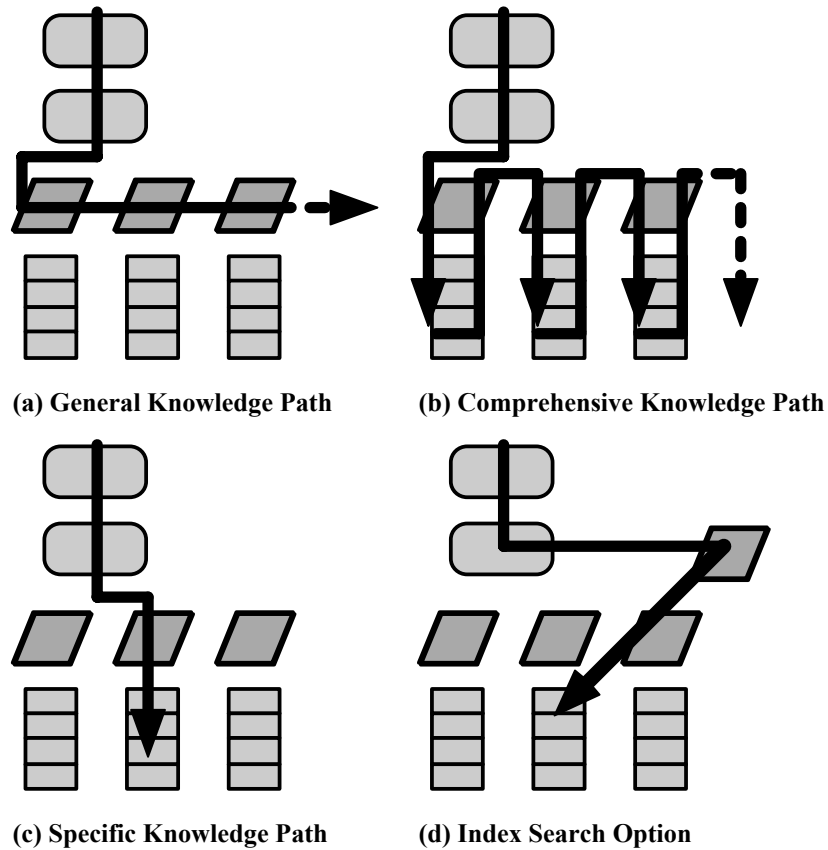
Figure 4 Modular structure for 'Smart Bridge' site



The content on any given page must support anticipated usage patterns. A user wanting a quick survey can sequentially visit the overview pages of the content sets as shown in Figure 5(a). Another user can explore the default path within each set that tells a comprehensive story as in Figure 5(b). A user with specific information needs can quickly bypass irrelevant information and create a rapid path to the desired content and detail, see Figure 5(c). Furthermore, if the appropriate path choices are not obvious, a

general index and a bridge site index are available to display the scope of the sites and link the user to desired information as shown in Figure 5(d).

Figure 5 Anticipated user paths: (a) path giving general knowledge, (b) path giving comprehensive knowledge, (c) representative path giving specific knowledge (d) index search option



The ‘Overview’ and ‘Photographs’ sets illustrate this progressively complex design with both simplicity and complexity elements of content. The content layering approach puts more comprehensive content and flexible options at each level within the site structure. ‘Overview’ guides the user to an overview presentation, but gives many categorised options for more detailed information such as abstracts and full files of published papers. ‘Photographs’ divides the available images into project phases and provides levels of image quality. The former set is primarily text based and the latter set is primarily image based. Also, html abstracts and thumbnail images provide clear previews with the option to download files or view higher quality graphics. Hence, general interests, special interests and WWW preferences of differing users are satisfied.

4 Summary

The WWW can be a useful tool for the documentation of significant projects and the dissemination of technical work. A well-organised site will accommodate the needs of all anticipated users. Text, graphics, interactivity, navigational aids, supplementary information, etc. must be judiciously integrated for effect. The concept of progressive complexity allows the users to tailor their own learning experience. This approach requires that content providers, instructional experts and WWW programmers work closely together. The design philosophy considers the WWW a unique media and guides the development and assessment steps purposefully.

The 'Smart Composite Bridge' component of the *Smart Engineering* WWW site is a model for communicating to a diverse audience and for balancing design elements of simplicity and complexity. The subject of the site, a prototype bridge, is a long-term demonstration of technologies for industry and a field laboratory for students. This WWW environment is a versatile learning vehicle that has components stimulating interest, providing technical details, illustrating protocols and documenting tests. It emphasises relationships among technologies, field applications and procedures more effectively than traditional documents and provides an up-to-date, accessible source of information. Consequently, the communication of research results and field demonstrations to both working engineers and students is enhanced. The site design is matched to anticipated user needs and content provider goals and it creates an instructional tool that can accommodate diverse needs of information delivery.

Acknowledgements

This World Wide Web development was supported by the National Science Foundation (NSF) through Combined Research-Curriculum Development Grant # EEC-9872546 with Mary Poats as technical contact. The Media Research Laboratory (Instructional Software Development Center) at the University of Missouri-Rolla provided the programming and assessment resources. The bridge development was primarily sponsored by the same NSF grant, the Center for Infrastructure Engineering Studies (UMR), the Navy Center of Excellence for Composites Manufacturing Technology (CECMT), the UMR Manufacturing Research and Training Center, Composite Products Inc. (John F. Unser, President), the Missouri Department of Transportation and the Missouri Department of Economic Development. Other supporting companies and organisations are noted at <http://campus/umr.edu/smarteng/>.

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