Communications of the Association for Information Systems

WIKI: A TECHNOLOGY FOR CONVERSATIONAL KNOWLEDGE MANAGEMENT AND GROUP COLLABORATION

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ABSTRACT

Wikis (from w*ikiwiki*, meaning "fast" in Hawaiian) are a promising new technology that supports "conversational" knowledge creation and sharing. A Wiki is a collaboratively created and iteratively improved set of web pages, together with the software that manages the web pages. Because of their unique way of creating and managing knowledge, Wikis combine the best elements of earlier conversational knowledge management technologies, while avoiding many of their disadvantages. This article introduces Wiki technology, the behavioral and organizational implications of Wiki use, and Wiki applicability as groupware and help system software. The article concludes that organizations willing to embrace the "Wiki way" with collaborative, conversational knowledge management systems, may enjoy better than linear knowledge growth while being able to satisfy ad-hoc, distributed knowledge needs.

Keywords: Wiki, knowledge management, conversational knowledge management, weblog, groupware, group decision support system.

I. BACKGROUND

On May 19, 2003 the New York Times published an article under the heading "New Economy: Businesses are starting to toy with the Wiki, an offbeat technology for fostering Web interaction" [Cortese, 2003]. The article reflects the current view of Wikis, as a knowledge management tool with significant potential impact, but little organizational acceptance at this time. Wikis are among the newest of several conversational technologies with an impact as knowledge management tools [Wagner et al., 2003].

Over the last several years, knowledge management gained increased attention as a source of competitive advantage. Rick Thoman, past CEO of Xerox, a two-time winner of the MAKE (Most Admired Knowledge Enterprises) Award, describes knowledge as the company's "life blood" [Barth, 2000]. At the same time, companies are struggling with effectively managing knowledge. A survey by Frappaolo and Wilson [2003] for instance shows that the majority of organizationally relevant knowledge (68%) still does not find its way into information systems.

Conversational knowledge management, generally facilitated through discussion forums and on-line communities, offered a model for low cost and high impact knowledge management, whether in the form of communities of practice for industries (e.g., once famous VerticalNet's communities

[Demers,2000]), or narrow discussion groups using Yahoo Groups [Schulte, 2002] or similar means.

Over time, conversational technologies grew beyond listservs or web based discussion forums. One of the newer technologies in this group is the Wiki, a collaborative tool that enables groups to jointly create content in an almost "anarchic" fashion. Wikis and their potential impact on knowledge management are the focus of this article. The questions guiding this exploration will be "do Wikis matter?" and (if so) "why do Wikis matter?"

The article is organized as follows. Section II discusses conversational technologies and their applicability to knowledge management. The characteristics and applicability for knowledge management and collaboration tasks are described in Section III. Section IV explores the organizational impact and potential hindrances to Wiki application. Section V draws conclusions and outlines future research directions.

II. CONVERSATIONAL KNOWLEDGE CREATION

Conversational knowledge creation emerged as the most popular way for organizations to create knowledge, largely in the context of online or virtual communities (e.g., [KPMG, 2003]). In conversational knowledge creation, individuals create and share knowledge through dialog with questions and answers. The Cluetrain Manifesto [Locke et al., 2000] strongly advocated this concept of conversational exchanges by postulating, for example, that "markets are conversations" (Table 1). The conversational model of knowledge creation is different from other models, where knowledge is for instance created through abstraction or aggregation of information, as in data or text mining.

Table 1. Cluetrain Manifesto Theses Related to Conversational Knowledge Management (3 out of 95).

Thesis	Content
1	Markets are conversations.
45	Intranets naturally tend to route around boredom. The best are built bottom-up by engaged individuals cooperating to construct something far more valuable; an intranetworked corporate conversation.
48	When corporate intranets are not constrained by fear and legalistic rules, the type of conversation they encourage sounds remarkably like the conversations of the networked marketplace.

Conversational knowledge creation contains several desirable features:

1. It can be economical and technology undemanding. Many on-line communities are built on little more than a listserv or a (freely available) web- based discussion forum.

2. Conversational knowledge creation is fast, taking potentially only as long as required for one person to post a question and others to post or e-mail a response. Speed makes conversational technologies particularly useful for environments where ad-hoc knowledge creation is required.

3. Conversational knowledge creation is suitable for environments where the knowledge is not centralized, but resides with multiple owners who may be located far apart.

Figure 1 captures the knowledge source and task repetitiveness dimensions and lists technologies that can satisfy the corresponding knowledge requirements.

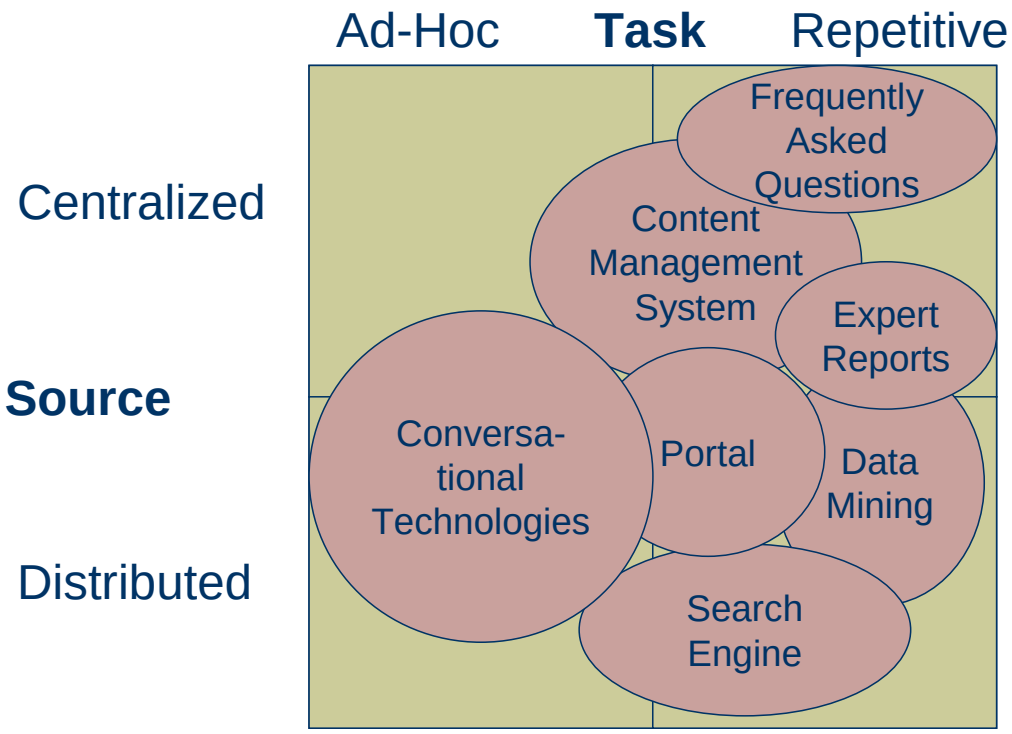

Figure 1 . KMS Fit Based on Knowledge Distribution and Task Repetitiveness

Figure 1 depicts numerous (typically expensive) enterprise technologies available to tackle repetitive knowledge requirements. These technologies are less applicable in ad-hoc tasks, when new knowledge must be gathered quickly (especially if the knowledge sources are far apart from one another). For example, an unexpected crisis may require a team of international experts to collaborate and explore possible solutions. Or, more mundanely, a global automobile company may need to analyze recent defects found in one of its cars. For such knowledge needs, conversational technologies appear to offer the best fit.

The corresponding types of conversational technologies are listed in Table 2 and are described below.

Table 2. Conversational Technologies

E-mail	Video and audio streaming
Static and database-backed web pages	Video and audio conferencing
Discussion forum	Weblog
Internet chat/instant messaging	Wiki

- *E-mail*. E-mail is predominantly a one-to-one or one-to-many conversation tool without a central knowledge repository or knowledge organization facility (unless provided as value-added features of the e-mail software). E-mail is the most essential IT based communication technology and the most widely used after the telephone.
- *Static and database-backed web pages*. Promoted by numerous free ISP services, Internet users broadcast their knowledge (e.g., within Geocities), or organized and commented on other people's knowledge (e.g., About.com). The "conversation" mode is generally one-to-many. But, due to the multitude of broadcasters, it can be considered an

unstructured, many-to-many conversation where communicators answer each other not directly, but through new posts on their web sites.

- *Discussion forum*. Discussion forums are a key online conversational knowledge exchange and the core technology for many on-line communities. The leading on-line community hosts (such as ezboard.com) manage the discussions of millions of communities[1]. Conversations are many-to-many, frequently with threaded discussions.

- *Internet chat / instant messaging*. Instant messaging is promoted through a number of free services, including ICQ and AOL Instant Messenger, each of which serves tens of millions of users. Instant messengers enabled multiple conversation modes from one-to-many to many-to-many. [De Maria, 2003; Goldsborough, 2001].

- *Video and audio streaming*. Video and audio streaming emerged as a popular technology for broadcasting (one-to-many communication). Unfortunately, almost all video and audio streams are neither indexed nor search engine friendly. When streams are recorded, they facilitate different-time communication. Also, records of communications require significant storage space, transfer speed, and human time to read them.

- *Video and audio conferencing*. Video and audio conferencing are popular for one-to-one or one-to-many communication, with partners meeting at the same time. Results can be recorded, but are usually not indexed and not search engine friendly. Also, records of communications require significant storage space, transfer speed, and human time to listen to them [van Horn, 1999; Fish et al., 1993]

- *Group decision support system (GDSS)*. Throughout the last two decades, GDSS have been a highly popular technology for small and medium-size groups meeting typically face-to-face and at the same time. Their objective is not so much knowledge management, but collaborative idea generation (group brainstorming) and consensus development [Gray and Mandviwalla, 1999; Watson et al., 1988]. Nevertheless, GDSS were used in a number of other application areas, including, for example, negotiation, learning, and crisis response, some of which do have a considerable knowledge management component.

- *Weblog*. A Weblog [Barger, 1997], is a personal web page, kept by the author in reverse chronological diary form. It is a “log on the web” and a “log of the web”. As a log on the web, it is kept first and foremost on the web, either on a static web page, or via a database-backed website, enabled through “blogging” software. As a log of the web, it frequently refers to other Internet locations via hyperlinking.

- *Wiki*. A Wiki is described as a set of linked web pages (and the application enabling its development), created through the incremental development by a group of collaborating users[2]. The Wiki’s uniqueness lies both in its software and in the use of the software by collaborating members.

Table 3 expands on Table 2 and summarizes the technologies according to their communication model, knowledge repository, and knowledge cataloging capabilities.

Among these conversational technologies, those with a permanent and searchable transaction record and those which facilitate end-user management are particularly useful. Among all of them this article focuses on the Wiki.

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[1] ezbord.com announced that it had hosted more than 1 million communities on March 1, 2002.
[2] Compare Leuf and Cunningham’s [1999] definition given at the beginning of Section III.

Table 3. Conversational Technology Overview

Technology	Communication	Knowledge Repository	Knowledge Catalog
E-mail	1-to-1, 1-to-many, person-to-person	Local e-mail archives possible	Local index possible
Static and DB backed web pages	1-to-many, approaching many-to-many, "dialog" between web pages through hyperlinks	Local archives	Local index possible, web rings create larger catalog
Discussion forum	Many-to-many in web based forums, repeated 1-to-many in list servers	Central repository if web based, local if list server	Central index if web based
Internet chat	1-to-1, many-to-many	Frequently none, transient communication	None
Video / audio streaming	1-to-many	Central host or decentralized streamers	None, streams not indexed.
Video / audio conference	1-to-1, 1-to-many	Local repository if content is recorded	None, content typically not indexed.
GDSS	Many-to-many	Available, but GDSS sessions often treated as one-off.	Typically none, but possible
Web Log	1-to-many, can approach many-to-many (similar to web pages)	Local repository within each weblog. "Metablogs" now emerging	Yes, local index, metablog may provide larger catalog
Wiki	Many-to-many	Yes, current knowledge and history ("temporal database")	Yes

III. WIKIS

WIKI DEFINITION

A Wiki is a set of linked web pages, created through the incremental development by a group of collaborating users [Leuf and Cunningham, 1999], and the software used to manage the set of web pages. The first Wiki was developed by Ward Cunningham in 1995, as the PortlandPatternRepository, to communicate specifications for software design. The term Wiki (from the Hawaiian *Wikiwiki* meaning "fast") gives reference to the speed with which content can be created with a Wiki. According to the Wikipedia (www.Wikipedia.org), an on-line encyclopedia implemented as a Wiki, Wiki key characteristics are:

- It enables web documents to be authored collectively.
- It uses a simple markup scheme (usually a simplified version of HTML, although HTML is frequently permitted).
- Wiki content is not reviewed by any editor or coordinating body prior to its publication.
- New web pages are created when users create a hyperlink that points nowhere (usually simply by writing a term in CamelCase, concatenating two or more words and capitalizing them)

Wiki design is based on eleven principles originally formulated by Ward Cunningham (e.g., http://c2.com/cgi/Wiki?WikiDesignPrinciples), shown in Table 4. The article will refer to these principles and their application repeatedly.

Table 4. Wiki Design Principles

Principle	Explanation
Open	If a page is found to be incomplete or poorly organized, any reader can edit it as he/she sees fit.
Incremental	Pages can cite other pages, *including pages that have not been written yet*.
Organic	The structure and text content of the site is open to editing and evolution.
Mundane	A small number of (irregular) text conventions will provide access to the most useful (but limited) page markup.
Universal	The mechanisms of editing and organizing are the same as those of writing so that any writer is automatically an editor and organizer.
Overt	The formatted (and printed) output will suggest the input required to reproduce it. (E.g., location of the page.)
Unified	Page names will be drawn from a flat space so that no additional context is required to interpret them.
Precise	Pages will be titled with sufficient precision to avoid most name clashes, typically by forming noun phrases.
Tolerant	Interpretable (even if undesirable) behavior is preferred to error messages.
Observable	Activity within the site can be watched and reviewed by any other visitor to the site.
Convergent	Duplication can be discouraged or removed by finding and citing similar or related content.

Figure 2 shows a Wiki page. It looks relatively similar to a regular web page or portal screen. However, buttons for edit, history, backlink, and other function suggest unique capabilities, including edit capability for everyone, as well as the ability to view previous page versions. Underlined text in CamelCase illustrates the user-friendly hyperlinking feature. These and other special characteristics of a Wiki can best be understood by looking at it in use. Hence, Wiki technology-in-use will be illustrated next. It is worth noting that the menu tab on the left side of Figure 2 contains numerous menu items which are unique to the implementation presented here (namely TikiWiki), but not common to Wiki software in general. Tiki Wiki is a portal with Wiki and content management functions, and the ability to configure the portal to satisfy individual user preferences. As the menu tab is not an essential Wiki element, the subsequent screen shots will not depict it.

WIKI ILLUSTRATION

A Wiki is a collection of webpages with several special publishing and collaboration features, reflecting the design principles listed in Table 4. The features are hardly noticeable in the published Wiki (Figure 2), but significantly improve the knowledge creation and sharing process. This section illustrates the key features. It makes use of the TikiWiki software (version 1.7), open source software written in the PHP language (www.sourceforge.net). Much of today's Wiki software is available as open source software, including MetaWiki (used for the Wikipedia), PHP Wiki, and PMWiki. The different implementations all apply Wiki design principles, but differ largely in their additional features. TikiWiki, for instance, adds numerous content management and groupware functions, including voting, workflow management, file and image galleries, and weblogging. PMWiki, by comparison provides basic Wiki capability, but no workflow or portal features.

Creating and Editing a Wiki Page

Creating and editing Wiki pages is necessarily a simple activity (*Principles: Mundane* and *Universal*). The Wiki author uses a web-enabled form field to enter the comment he or she wishes to publish. Authors can use plain text or often a simplified mark-up language, although more sophisticated implementations (e.g., TikiWiki) may also allow the use of HTML. Figure 3

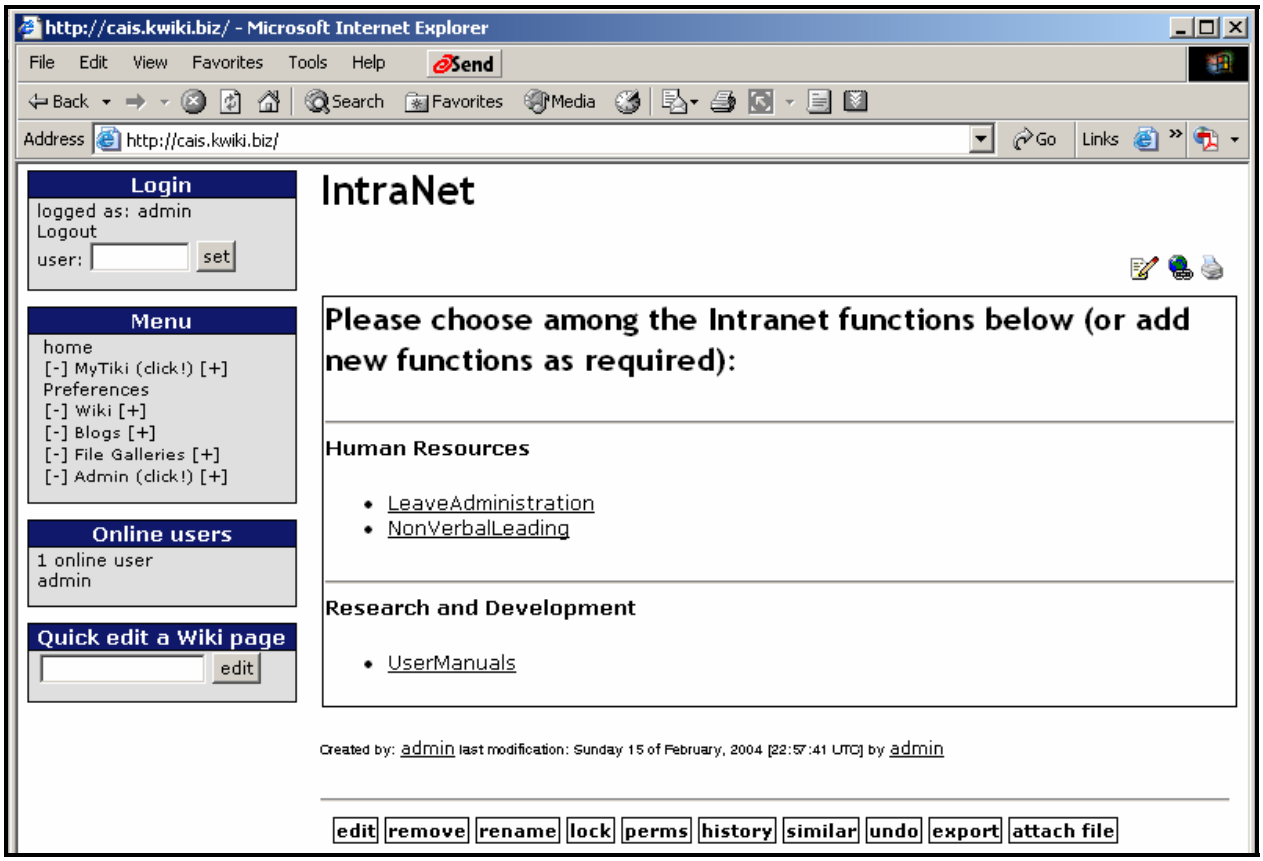


Figure 2. Wiki Screen

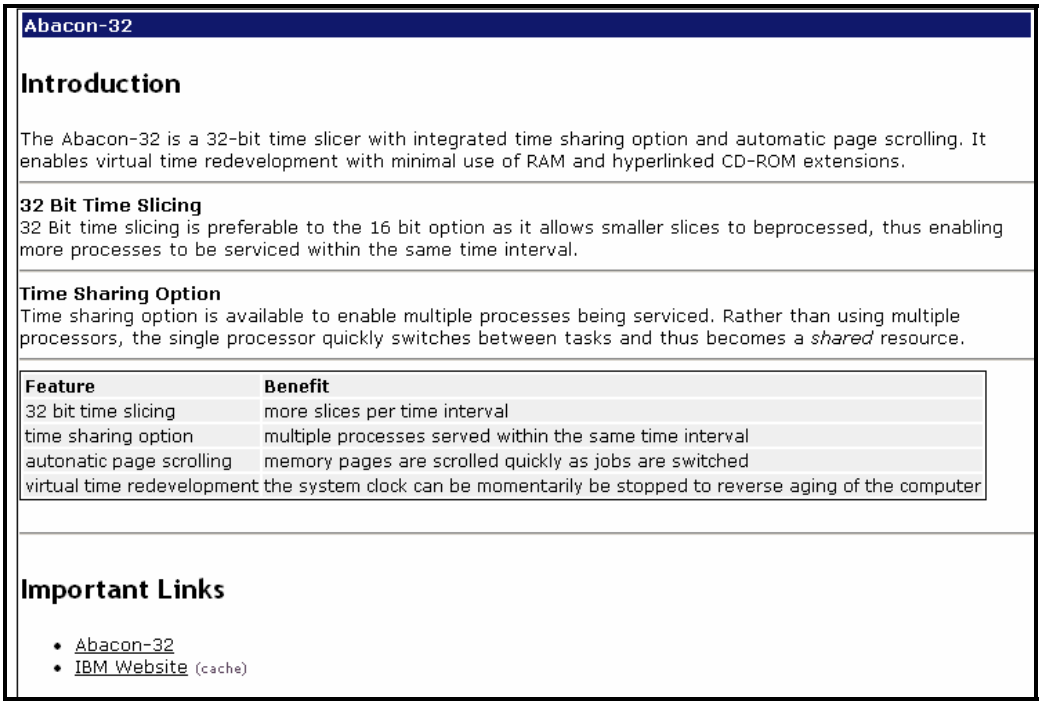


Figure 3. Wiki Rendered Webpage

shows the rendered webpage a user would see created from the input text and Wiki-unique formatting characters. Figure 4 shows a TikiWiki edit screen with special formatting characters. Although text creation is relatively simple, a typical feature of Wikis is the “sandbox” where less experienced writers can create content on a trial basis and hone their publishing skills if desired. The sandbox looks identical to the edit screen in Figure 4, but it does not record page histories.

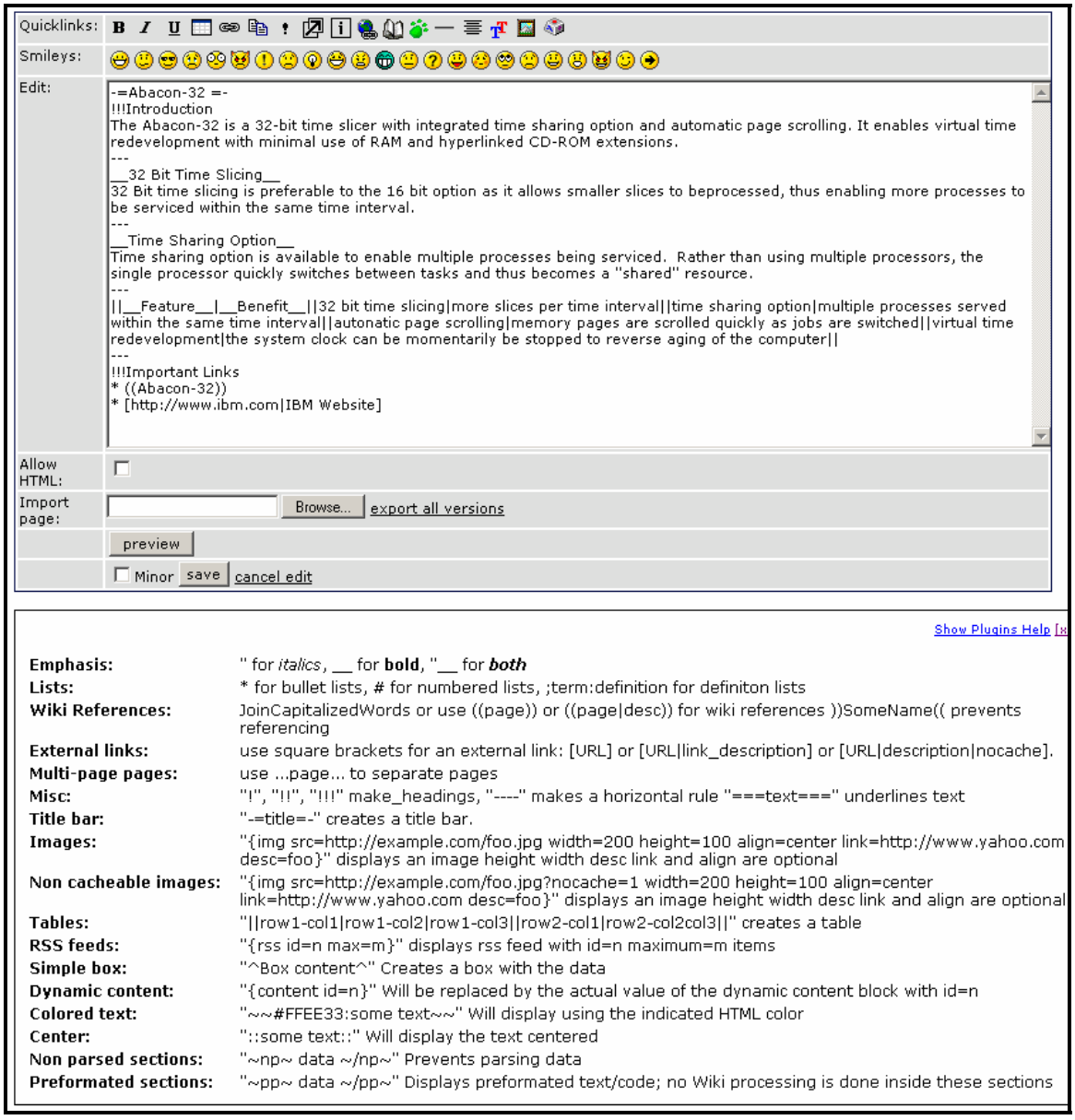


Figure 4. Wiki Edit Screen

CREATING A HYPERLINK

The use of hyperlinks is a fundamental aspect of knowledge management with Wikis. Hyperlinks connect topics and create context (*Principle: Open*). Wiki design makes hyperlinking easy. Users do not have to create and use URLs. Instead they use CamelCase (multiple words capitalized and concatenated) to create a link. Figure 5 illustrates both the use of the CamelCase

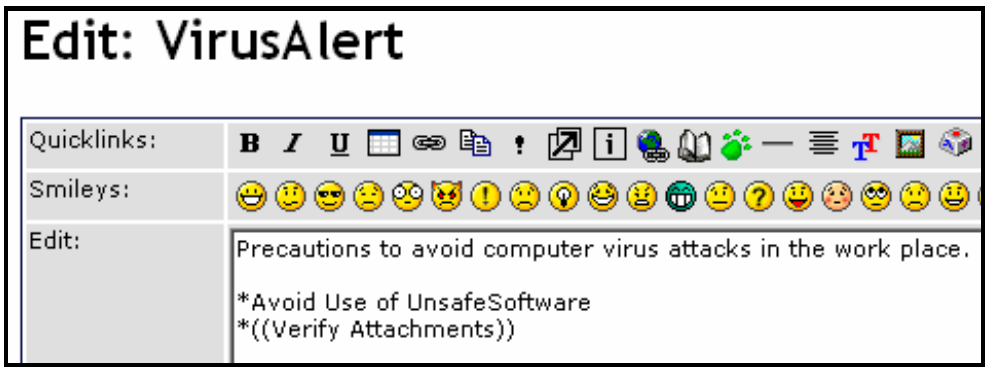


Figure 5. Use of CamelCase and Parentheses for Hyperlinking

(e.g., "UnsafeSoftware") in the edit screen, and another hyperlinking method using double parentheses. Figure 6 shows the result in the published Wiki page. Note that the second hyperlink appears in familiar fashion, as an underlined word. The first hyperlink appears as a question mark. The question mark indicates a "link" to a not yet existing page (*Principle: Inremental*). Creating a Hyperlink

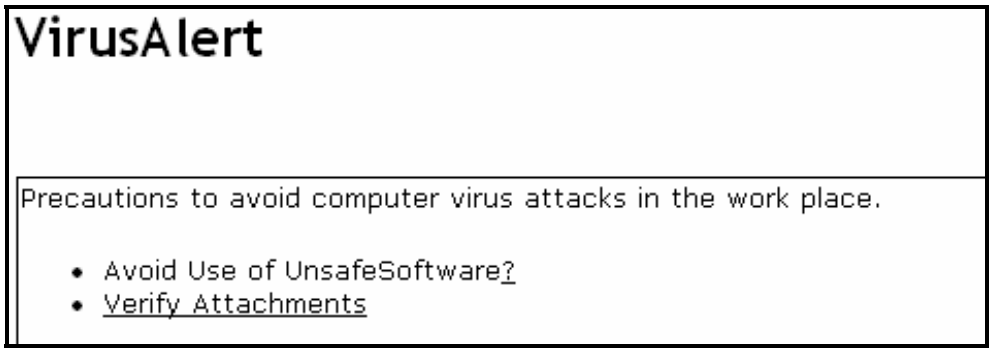


Figure 6. Hyperlinking – Published Wiki Page (Partial View) with Hyperlinks

The Wiki also automatically creates reverse links (backlinks) from destination pages to all pages that refer to them. This convention enables bi-directional Wiki navigation without the browser's BACK button. Users therefore can always explore the entire Wiki web, independent of their entry point into the Wiki. Figure 7 shows a single backlink from page "Verify Attachments" to page "VirusAlert".

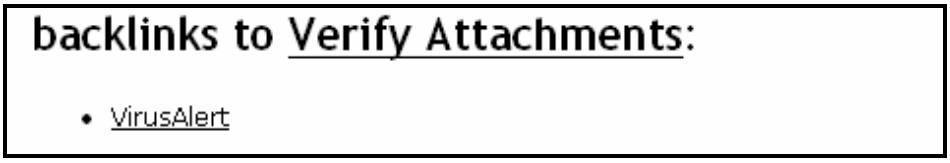


Figure 7. Backlink Mechanism

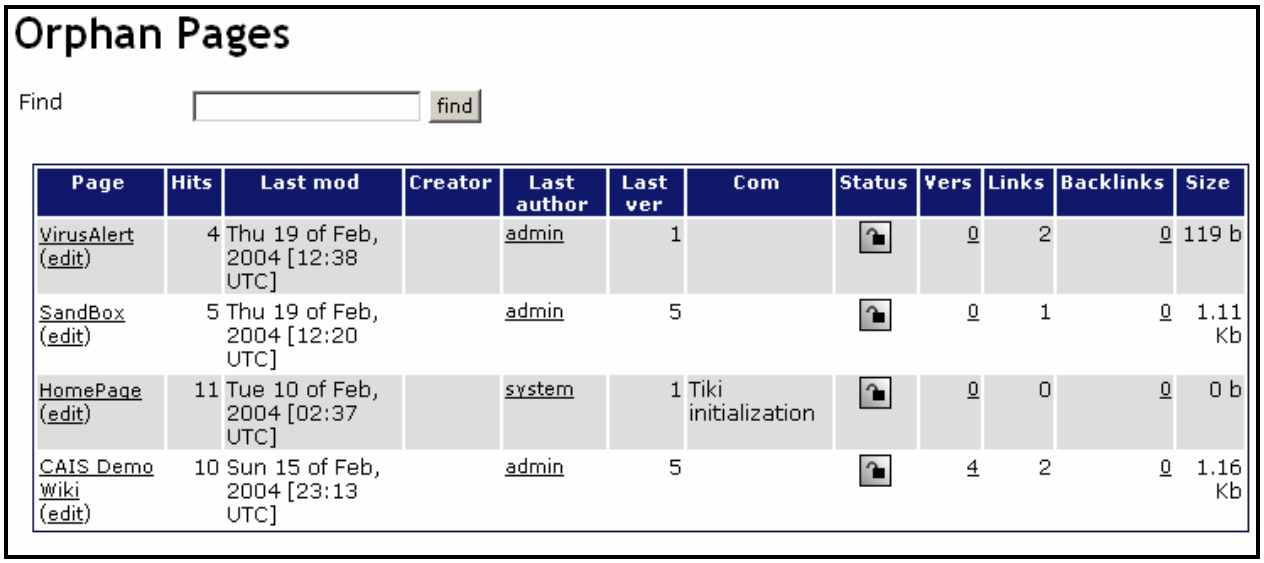
Multi-user Wiki Modification

Wiki technology is a multi-user technology. Consequently it incorporates several features that simplify multi-user web pages creation and manipulation (*Principles*: *Incremental* and *Organic*). These features include provisions for multi-user access and features to avoid conflict or inconsistencies arising from multi-user edit capabilities.

Orphaned Pages and Open Links

With multiple people working on a Wiki, tracking and connecting all existing pages meaningfully can become difficult. Hence, an important Wiki feature is a directory function; in particular a directory that shows all orphaned pages, i.e., those without links to them. Contributors can consult this directory to organize the existing knowledge more cohesively and to create more context. Figure 8 shows a list of orphaned Wiki pages. The directory enables direct access to each of these pages.

Open links are another maintenance issue for web sites in general. Wikis show open links usually as questions to be answered (see Figure 5). This feature helps the original creator and collaborators to identify content that needs to be generated.



Orphan Pages

Find find

Page	Hits	Last mod	Creator	Last author	Last ver	Com	Status	Vers	Links	Backlinks	Size
VirusAlert (edit)	4	Thu 19 of Feb, 2004 [12:38 UTC]		admin	1			0	2	0	119 b
SandBox (edit)	5	Thu 19 of Feb, 2004 [12:20 UTC]		admin	5			0	1	0	1.11 Kb
HomePage (edit)	11	Tue 10 of Feb, 2004 [02:37 UTC]		system	1	Tiki initialization		0	0	0	0 b
CAIS Demo Wiki (edit)	10	Sun 15 of Feb, 2004 [23:13 UTC]		admin	5			4	2	0	1.16 Kb

Figure 8. List of Orphaned Wiki Pages

Versioning and Page History

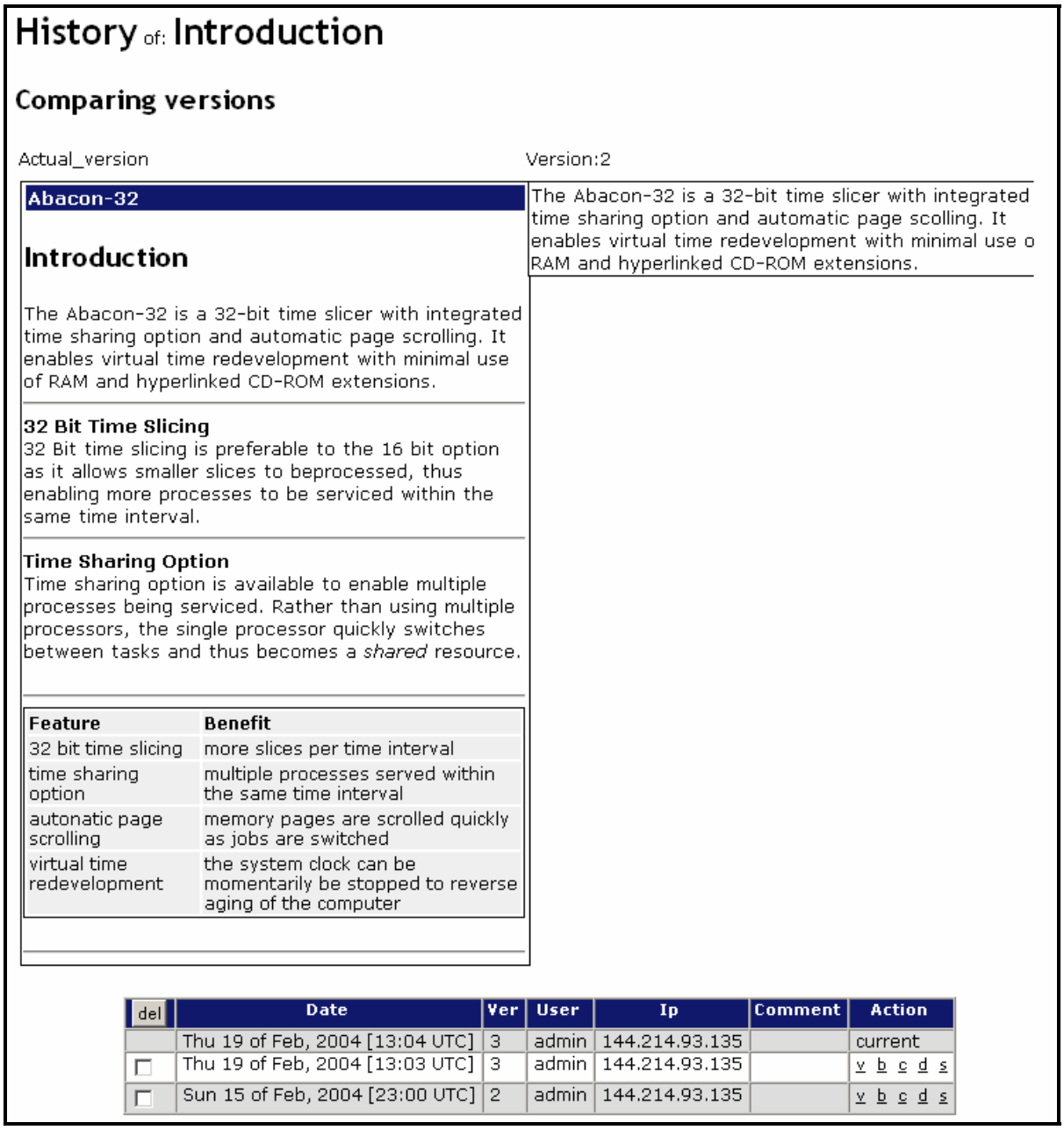
As multi-user systems, Wikis allow any user to modify any other user's web pages (unless specifically limited by access right settings). This property creates numerous challenges in version management. Wikis address these challenges by keeping prior versions of any web page in memory, and enabling rollback, comparison, difference identification, and similar functions, if so desired (Principle: Observable). Furthermore, the Wiki provides a history of prior changes with author, date, and related information, as well as potentially a comment explaining the change. Figure 9 shows a page version comparison and the corresponding page history table.

KNOWLEDGE MANAGEMENT NEEDS AND WIKI CHARACTERISTICS

As a conversational knowledge management technology, Wikis are able to address a specific set of knowledge needs. This section explores these needs, and the Wiki features that facilitate them.

Knowledge Needs

As a conversational technology, Wikis should be most effective for ad-hoc problems with decentralized knowledge sources [Cheung et al., 2004]. While Wiki use is not limited to this area (as illustrated in a later section), Wikis possess a unique competitive advantage in this problem



History of: Introduction

Comparing versions

Actual_version

Abacon-32

Introduction

The Abacon-32 is a 32-bit time slicer with integrated time sharing option and automatic page scrolling. It enables virtual time redevelopment with minimal use of RAM and hyperlinked CD-ROM extensions.

32 Bit Time Slicing
32 Bit time slicing is preferable to the 16 bit option as it allows smaller slices to beprocessed, thus enabling more processes to be serviced within the same time interval.

Time Sharing Option
Time sharing option is available to enable multiple processes being serviced. Rather than using multiple processors, the single processor quickly switches between tasks and thus becomes a *shared* resource.

Feature	Benefit
32 bit time slicing	more slices per time interval
time sharing option	multiple processes served within the same time interval
autonatic page scrolling	memory pages are scrolled quickly as jobs are switched
virtual time redevelopment	the system clock can be momentarily be stopped to reverse aging of the computer

Version:2

The Abacon-32 is a 32-bit time slicer with integrated time sharing option and automatic page scolling. It enables virtual time redevelopment with minimal use o RAM and hyperlinked CD-ROM extensions.

del	Date	Ver	User	Ip	Comment	Action
	Thu 19 of Feb, 2004 [13:04 UTC]	3	admin	144.214.93.135		current
☐	Thu 19 of Feb, 2004 [13:03 UTC]	3	admin	144.214.93.135		v b c d s
☐	Sun 15 of Feb, 2004 [23:00 UTC]	2	admin	144.214.93.135		v b c d s

Figure 9. Wiki Page Version Comparison and Page History Table

area. In exploring knowledge needs, the following discussion differentiates between knowledge users and knowledge creators because their needs differ.

Knowledge User Perspective

In a knowledge management environment, those interested in obtaining knowledge have several specific concerns.

Ad-hoc knowledge. Knowledge users are likely unable to specify their knowledge needs *a priori*. As a result, they rely on a just-in-time knowledge management tool that can satisfy the needs as they arise, i.e., a tool that incorporates fast question answering.

Finding the knowledge. Locating knowledge is a major challenge in any knowledge management system. Users want to find knowledge if it is available in the system. Since today's advanced search engines such as Google employ not only basic keyword search, but also more advanced hyperlink and hyperlink popularity interpretation [Thelwall, 2002], users will benefit from a tool which is "search (engine) friendly", and thus keyword oriented, hyperlinked, and indexed.

Filtering knowledge from noise. Filtering is the complement to the previous need. Users want to find knowledge, but only if it is relevant. In discussion forums, relevance is frequently an issue as there are often numerous replies to any question, with different levels of usefulness and relevance. Hence, to convey context a tool with advanced search engine and hyperlinking capabilities is beneficial.

Quality of the source. Quality assurance is a user concern, specifically the quality of the knowledge source. Users need to judge how reliable they deem the knowledge to be. Hence, a knowledge management tool is needed to incorporate quality assurance mechanisms, including the tracking of knowledge sources.

Knowledge Creator Perspective

From a knowledge creator's point of view, the knowledge management system must also address several needs.

Dynamically changing knowledge. Maintaining knowledge is exceedingly difficult when that knowledge changes rapidly. For example, in cases of a breakout of an unknown disease (such as SARS) or similar disastrous event, new pieces of knowledge need to be created, collected, and disseminated as quickly as possible to facilitate a global problem solving process. In such a situation, the technology needs to support distribution of knowledge creation activities to as many participants as possible.

Distributed knowledge. In most cases, collective knowledge is superior to the knowledge of any individual. Consequently, frequently knowledge is well defined (i.e., be relatively static), but no single individual possesses it all. And, even if there are a few key experts, these few may be unable to record all their knowledge or state it in ways meaningful to everyone else. Hence, the knowledge management tool should be able to combine the knowledge of multiple experts seamlessly.

Errors and recovery (quality assurance). Inevitably, the knowledge base will be incorrect at some points in time. It may state wrong facts or omit relevant knowledge. The knowledge management tool therefore benefits from self-correcting mechanisms that quickly correct any errors in the knowledge base. This capability is another aspect of quality assurance, but one that focuses on knowledge creation and maintenance, instead of the knowledge user.

Publication overhead. Knowledge creators should not need to worry primarily only about the knowledge content. Message representation and posting on a shared knowledge repository should be fast, easy, and secure.

Wiki Characteristics

Wikis can, in their application as a collaboration technology, address many of the abovementioned needs. This section identifies particular Wiki characteristics that enable these knowledge management capabilities. These characteristics are not so much individual features, which were illustrated earlier, but Wiki functional aspects that are derived from a combination of the technology, the practice in which it is used, and the input of its participants.

Incremental knowledge creation as question answering. Wikis combine multiple sets of knowledge gracefully. Individuals are able, and even encouraged, to begin creating knowledge content that is incomplete (or even erroneous) and then to rely on other collaborators to add content. The ability to "ask questions" by creating hyperlinks to non-existing pages distributes the

effort. The incremental way in which knowledge is created, also means that the newest version of each page likely contains the best content. Hence, users generally do not need to search through archives or page histories to find the best content.

Power of N. Wikis create joint ownership of the work product. Each person can add to each other's pages and can make changes. This Wiki technology feature is based on its design principles (*Open* and *Incremental*). If it is combined with proper guidelines for editing and use (as, for example, demonstrated in the Wikipedia) and observability of participant actions (*Principle: Observable*), it enables a community to share its knowledge freely. Community members can help each other in correcting mistakes and work as a high performance team instead of a command-and-control structure that waits for an editor to approve additions or changes, and to answer questions. The "Power of N" also plays an important role as a safety and reliability feature. For any individual who attempts to maliciously alter or remove Wiki content, there are many others who quickly repair the damage (using for instance the Wiki's rollback mechanisms).

Centralized, web based resource. Wikis support a decentralized group of conversationalists, but the technology infrastructure is designed to be centralized. Wikis use a common repository, i.e., database server, an application server that runs the Wiki software, and a web server that serves the pages and facilitates the web-based interaction. Wikis are thus available anytime and anyplace where there is web connectivity, and have a single common knowledge repository. As a result, they enable and empower multiple users to collaborate whenever and wherever on the same, centrally stored, knowledge product, able to see and use the entire work product.

Content-to-page mapping (Granularity). The basic unit of information in a Wiki is a web page. This property, in itself, is an advantage over other conversational media such as discussion forums, where the same concept may be discussed within multiple postings belonging to one or more threads, or where one message may shift the topic focus elsewhere, thus covering more than one knowledge concept in one message. In a Wiki, if there is a mismatch between knowledge concepts and Wiki pages, it can be adjusted, either by breaking the content into multiple pages, or by combining multiple pages into one. If multiple pages cover the same topic, part of the editing guidelines would suggest combining their contents (*Principles*: *Organic* and *Convergent*). Thus, Wikis can achieve a one-to-one mapping between knowledge concepts and their representation within the Wiki.

Indexed content. Since each concept is specific to one web page, its URI is unique, and therefore can be indexed and searched. As a result, knowledge concepts can be catalogued individually and found easily even by search engines incapable of full text search. This advantage loses some of its importance when content is spidered and indexed by quasi-fulltext search engines such as Google.

Hyperlinks to create context. Hyperlinks connect concepts to other concepts, thereby creating context. Aside from the obvious advantage of allowing readers to make connections and to drill down into detail knowledge, hyperlinks are also a potential quality assurance mechanism and relevance indicator. Pages with many links to them indicate a highly useful page. Furthermore, the context identified by a page's hyperlinks (and hyperlinks pointing to it) help define the meaning of a page to a search engine. Modern search engines such as Google are able to interpret link information accordingly (http://www.google.com/ technology/index.html; [Thelwall, 2002]). Hence, the ease with which hyperlinks are created in a Wiki is an important factor in promoting content relevance and quality. To create further context without effort to the user, Wikis can also automatically create backlinks (reverse links to the page from where the initial link originates). Backlinks enable convenient backward navigation, changes any hierarchy of web pages into a network, and makes the entry point into a set of Wiki pages less relevant, since users can start at "the bottom" and navigate along the backlinks "upward" to other knowledge concepts.

Work product orientation. In a Wiki, the work product, the knowledge content in its iteratively improved form, is the focus of attention. This focus differs from other conversational technologies. In same-time-same-place GDSS such as the initial versions of GroupSystems [Nunamaker et al., 1991], for example, the process is dominant, and participants are forced into the process with mandatory inclusion/exclusion and relatively rigid timing[3]. Timing constraints makes such systems less useful for different-time interaction where people work on different parts of a problem or different parts of a knowledge base on their schedule.

In total, Wiki characteristics enable it to address many knowledge needs, as summarized in Table 5. Notably, a Wiki's capability to bring together the input of multiple participants (Power of N) addresses several knowledge user needs, leading to more and better knowledge. Furthermore, Wiki characteristics enable other uses than simply conversational knowledge creation.

Table 5. Knowledge Management Needs and
Corresponding Wiki Design Principles, Characteristics, and Features

User Needs	**Principles**	**Wiki Characteristics and Features**
Ad-hoc knowledge	Incremental, Organic, Universal	Incremental knowledge creation as question answering; Power of N; Wiki editing features (speed of publication)
Finding knowledge	Unified, Precise, Incremental	Knowledge indexing and hyperlinking; Backlinking; Centralized, web-based resource
Filtering knowledge from noise	Unified, Precise, Convergent	Hyperlinking; Power of N; Removal of duplication
Quality of source	Open, Organic, Observable	Power of N; Record of history of changes with author information; Ability to comment on changes
Dynamically changing knowledge	Organic, Observable	Power of N; Wiki editing features (history and version management)
Distributed knowledge	Organic	Power of N
Errors and recovery	Open, Tolerant, Observable	Power of N; Wiki editing features (history and version management)
Publication overhead	Mundane, Universal, Overt	Wiki editing features; Wiki publication features

WIKI APPLICATIONS

This section describes two of the many Wiki applications: Wikis as groupware and Wikis as a technology to implement help systems. The applications illustrate Wiki strengths and highlight their ability to replace existing information system solutions. Wkis as groupware stress the collaborative capabilities of Wikis in areas where knowledge may be changing dynamically or where viewpoints differ about the knowledge. The focus in applying Wikis as a help system (e.g., help facility or help desk) is on capturing a known but yet to be formalized body of knowledge that may need the contributions of several participants. The emphasis in this second example is on the knowledge structure and representation in a question-and-answer format. Another, and likely one of the most successful Wiki applications to-date, namely as an on-line encyclopedia (the Wikipedia), will be explored in a later section.

[3] Later versions of GroupSystems provided different time and/or different place capabilities, but these capabilities were not the dominant use to which GroupSystems was put.

Wikis as Groupware

If we compare conversational technologies in terms of time and place, they can be separated into three classes as shown in Figure 10. Group Decision Support Systems design features targeted their use as a same-time, same-place technology [e.g., Gray and Mandviwalla, 1999; Nunamaker et al., 1991]. Implemented with client-server technology and a work flow that facilitated the activities of group brainstorming, idea categorization, and choice (voting), they sought to remove the hindrances of face-to-face meetings and to amplify the positive aspects of such meetings.

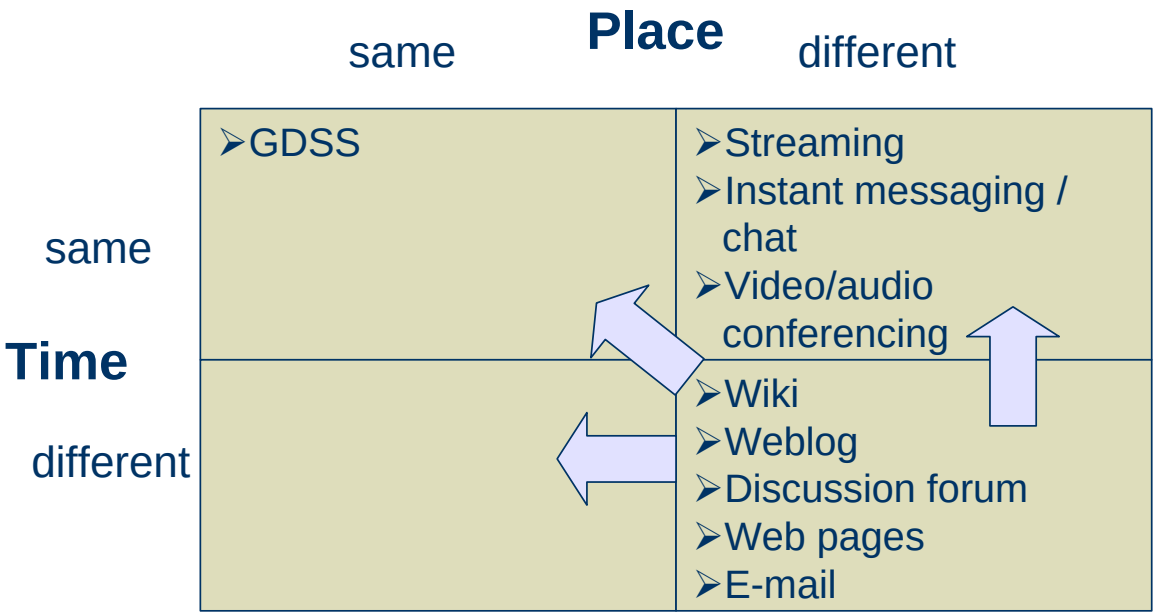


Figure 10. Conversational Technology Applicability in Collaborative Environments

Wiki characteristics stand out for same-time, same-place GDSS because:

1. They incorporate a many-to-many knowledge creation and sharing model, instead of the one-to-many model propagated, for example, in weblogs, e-mail or websites.

2. Wiki knowledge organization is topical. Contributions are organized foremost by topic (and then chronologically), instead of being organized chronologically first, as is typical with weblogs, discussion forums, or e-mail.

Possibly the best way to use Wiki technology as a GDSS is to adopt an approach of brainstorm-aggregate-feedback. This approach is analogous to the Delphi method [Dalkey and Helmer, 1963], but without the use of questionnaires. During a first brainstorming phase, users would create Wiki pages one-by-one, while possibly being allowed to read, but not edit each other's pages. During an analysis and aggregation phase, idea category pages would be created and hyperlinked to the previously created brainstorms. In a subsequent iteration and feedback phase, users could then comment on the idea categories, add specifications and detail, and provide their evaluations. Using a tool such as TikiWiki, users could rate each other's comments, therefore enabling a rudimentary voting scheme.

The Wiki approach to making connections via CamelCase hyperlinking, and the inducement to create hyperlinks to not yet existing pages (question marks), should also affect group creativity positively, since making connections is one of the driving forces of creativity [e.g. Sternberg, 1988; Koestler, 1964; Holyoak and Thagard, 1989],

We should note that the use of Wikis instead of GDSS may result in process losses. For example, users at different locations must not edit the same Wiki page at the same time. With

Wiki pages not being locked (unlike database records), concurrent editing by multiple collaborators will result in page versions being overwritten unintentionally, thus undermining incremental content improvement. Consequently users have to either work on different pages, which can later be combined and aggregated (extra process step and process loss), or need to work sequentially .

"Help Facility" Wiki

An important class of software applications are knowledge management systems that provide interactive help. These applications include embedded systems, such as the help function of applications software, as well as helpdesk applications to facilitate customer support. Frequently these systems analyze a problem by traversing through a hierarchical search tree, ruling out irrelevant nodes through question and answer dialog, and then relay the most appropriate response for the given condition. In the past, such systems were implemented through a range of technologies. During the 1980s, expert systems emerged as a technology particularly suited for this task type. Expert systems were successful in a number of well-publicized applications, but also suffered from several weaknesses, such as their brittleness at the limits of the embedded expert knowledge, narrow domain focus, maintenance difficulty, and the role conflict between domain expert and knowledge engineer [e.g., Hayes-Roth et al., 1983; Waterman, 1986].

Wikis offer an opportunity to acquire the expertise needed for help system development in a less rigid, incremental manner. The resulting system would be able to answer questions based on expert knowledge, but without the formal knowledge base and reasoning mechanism in artificial intelligence implementations.

To create a help facility in a Wiki, the developers, i.e., knowledgeable end users, would begin by defining a "root" question, as Figure 11 illustrates. For example, an insurance claims adjuster might reflect on "how do I determine the proper payment for a product liability claim?" This question would be successively broken down into sub-questions to define alternative cases (e.g., how to determine basic damages). Unknown concepts would be clarified via explanation pages

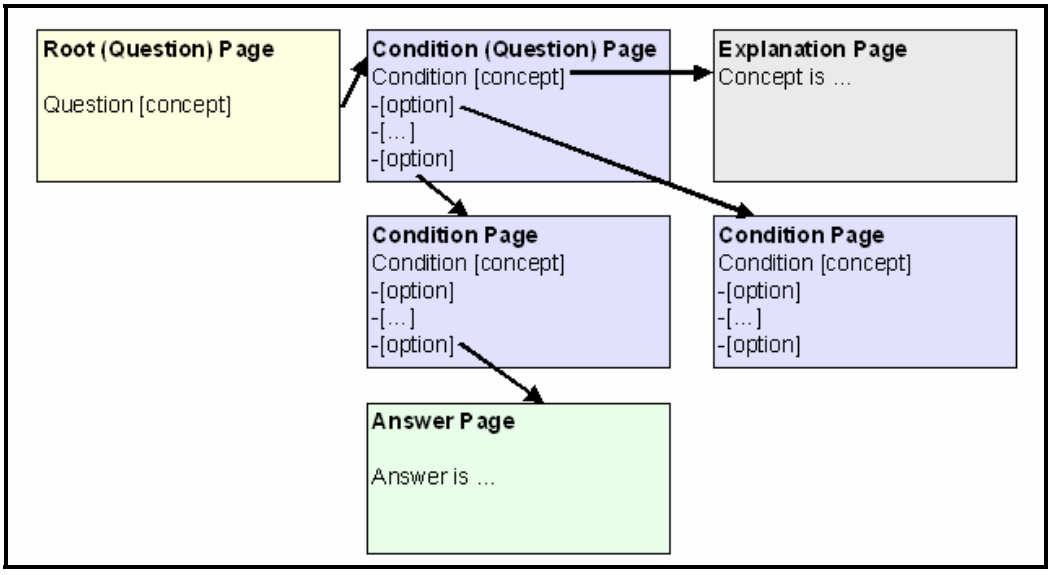


Figure 11. Help Facility Wiki Argument Flow

("why determine basic damages?"), which could be continuously added, as needed, through the use of CamelCase hyperlinks. Leaf nodes of the resulting web would be answer pages.

The incremental approach to building Wikis would enable the creation of an incrementally growing system containing the shared knowledge of multiple sources. Thus, a group of helpdesk

experts can jointly create a helpdesk knowledge base that covers a wide range of conditions and answers. The use of the experts' natural language would support knowledge base maintainability, which would also be improved by users adhering to Wiki editorial guidelines, such as refactoring rules.

Still, this design involves some clear limitations. Its structure is largely hierarchical, although condition and explanation pages can potentially be re-used, thus enabling a quasi-network structure. Intermediate results (earlier user responses) would not be retained, thus eventually leading to user being asked the same question multiple times. Notwithstanding these limitations, the simplicity of knowledge definition and maintenance, and the well-understood user interface can enable the creation of very functional, end-user maintainable, knowledge based systems. Figure 12 shows a screen from an embedded help system within a web-enabled Balanced Scorecard software (author's implementation). The help system (developed with PMWiki) explains the software to the user but, at the same time, can also serve as a "wizard" which moves directly to the scorecard software's functions, through active hyperlinks.

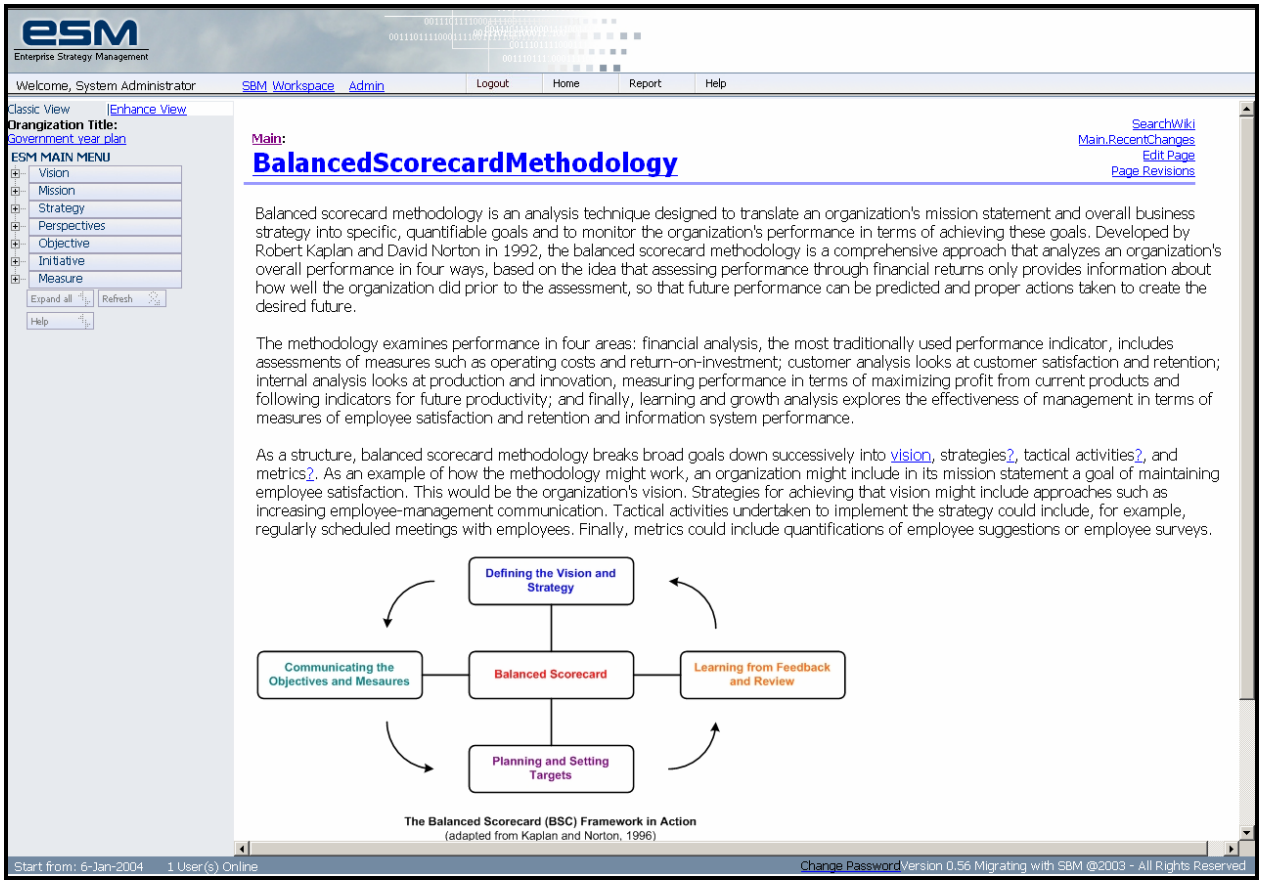


Figure 12. Embedded Help System Using PMWiki

Being a Wiki, the help system is user modifiable, so that when users encounter new "tricks" (or problems) in using the software, they can immediately document them in the help facility and thus share their growing expertise with other users.

IV. IMPLICATIONS FOR THE USE OF WIKIS

PARADIGM SHIFT

Wikis could be characterized as promoting knowledge management by anarchy. Contrary to most other knowledge management solutions, there is no single knowledge owner, but knowledge is "owned" by all creators. Furthermore, Wikis in principle do not involve restrictions on editing rights, thus enabling anyone to modify anyone else's knowledge. While this privilege arguably creates the potential for knowledge vandalism, the corrective powers of a large ownership, combined with the ease or rolling back earlier Wiki versions make Wikis relatively robust. Furthermore, there is little challenge for potential vandals in attacking a wide-open application. Nevertheless, it is clearly this characteristic of Wikis, the joint ownership combined with open access, which makes Wikis both powerful and controversial to use. This idea is reflected in published accounts of users who at first "didn't get it" and later found the Wiki to be an essential tool [Leuf and Cunningham, 2001], (see foreword by Jeffries), or to become a self-proclaimed "Wiki addict" (e.g., http://c2.com/cgi-bin/Wiki?KenRawlings).

KNOWLEDGE DOCUMENTATION RULES

Although a Wiki can be modified by anyone in any way, advanced Wiki applications have developed guidelines and procedures for editing etiquette, as well as editing effectiveness. Guidelines for editing etiquette may be as simple as to suggest to "clean up your own Wiki pages first before starting to edit others", thus trying to minimize unnecessary conflict between multiple authors over content changes.

Guidelines for effectiveness editing are established to make the resulting content as meaningful as possible to readers, and are extensions of Wiki design principles. The guidelines, in part, also resemble software generation guidelines, such as rules for extreme programming [Beck, 1999]. For example, the refactoring rules listed at the C2 website (http://c2.com) explain how to make text more readable, such as (original text follows indented, without typing or grammar corrections):

> **"Delimit conversation**
> - *Use signature lines* to separate thoughts expressed in thread mode. Make the signatures part of the paragraph. This works best when thoughts are expressed as a single paragraph. This transformation becomes easier as a page matures and the important ideas become obvious. Use an empty signature (" -- ") when the author is unknown or wishes to remain anonymous.
> - *Use horizontal rules* to separate a contribution with several paragraphs from other contributions when an author's idea is sufficiently complex or well developed that it requires many paragraphs.
> - *Use inline comments* [inside square brackets like this,] for very short editorial comments. Consider rewriting the paragraph to make the addition unnecessary.
> - *Use Unsigned comments*, that become part of the flow of the page. Other than being offset from signed contributions unsigned work should blend seamlessly with the page as a whole." [4]

These guidelines go beyond style, but are targeted at combining comments from multiple users in lean, clear form, so as to avoid for instance the convoluted structure of discussion forums, with sometimes long threads that lack organization or quality assurance (*Principles: Open, Unified, Precise,* and *Convergent*).

An extension of these guidelines for knowledge documentation may lead to the design of "thinklets" [Briggs et al., 2003] for collaborative knowledge creation with Wikis. These thinklets

[4] From http://c2.com/cgi/Wiki?RefactoringWikiPages

might guide, for instance, the asking of questions (open links), answering, commenting, and linking, and therefore help knowledge workers in the creation of well structured, knowledge-rich Wikis.

WIKIS AS A FORM OF OPEN SOURCE SOFTWARE

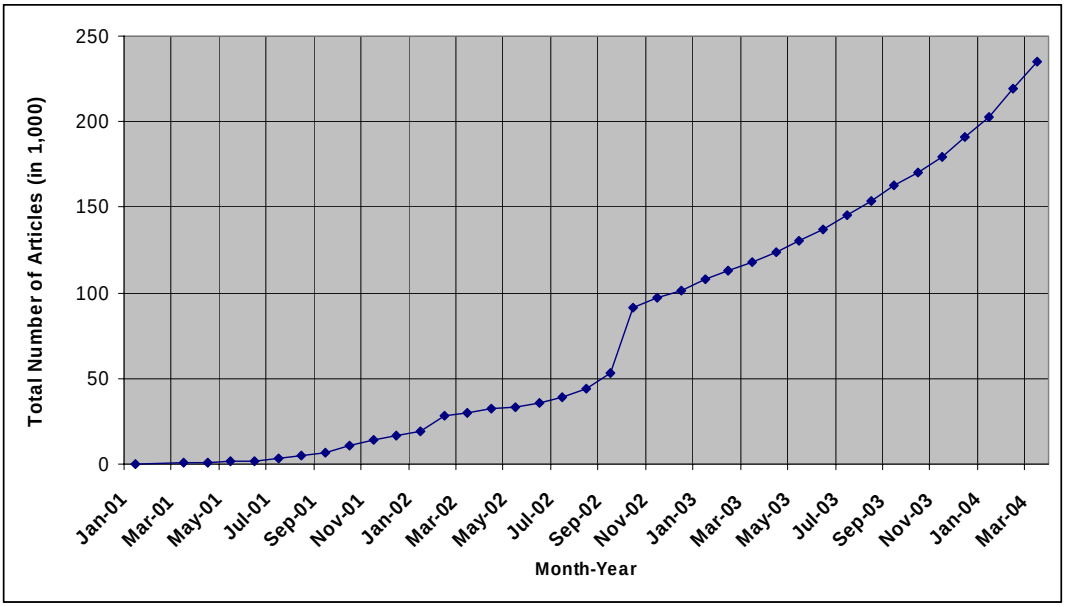
Knowledge management using Wikis bears considerable resemblance to open source software development [Markus et al., 2000], including the following traits:

- Mutually reinforcing motivations, such as sharing in the collective success,
- Work product open to the public and therefore easy to monitor,
- Reliance on the voluntary efforts of multiple distributed participants to make enhancements,
- Self-governance of the developer team,
- Task decomposition for more development efficiency,
- Use of technology for communication and coordination and norms on how to use the technology..

Open source software development has had remarkable successes, creating software that appears to break longstanding rules of software evolution [Scacchi, 2003], especially with respect to code growth. For example, open source software size has been shown to grow super-linear (exceeding linear), rather than linear or even less aggressive. Similarly, open source software developers appear to be more productive than those working on proprietary projects [Mockus et al., 2002]. Wikis may offer the same productivity advantages for knowledge bases, as suggested for instance by the knowledge growth and growth acceleration within the Wikipedia encyclopedia.

EFFECT OF 'POWER OF N' AND PUBLICATION SIMPLICITY

The combination of ease and speed of publishing content together with the ability of engage a potentially large group into the knowledge creation process, enables Wikis to become a platform for very large and up-to-date knowledge repositories. This is best illustrated by the Wikipedia, an on-line encyclopedia implemented as a Wiki. As of March 2004, the English Wikipedia contained about 235,000 articles with over 56 Million words in total. Figure 13 illustrates the growth trend in



Source: http://www.wikipedia.org/wikistats/EN/TablesArticlesTotal.htm

Figure 13. Wikipedia Article Volume from Inception in 1/2001 Until 3/2004

article creation since inception of the Wikipedia. Furthermore, articles are updated so frequently, that major events are included in them typically within 24 hours. For example, during the SARS epidemic, the Wikipedia would report daily updated figures on new cases. The Wikipedia also reported on Martha Stewart's indictment on the day it happened. Reviews of the history of active pages often show multiple modifications per day and dozens of modifications within a month.

While the exact number of Wikipedia active editors (authors) is not known, Amjadali [2003] reports between 150 and 200 regular editors, but also thousands of additional anonymous contributors. Mayfield [2003] refers to several thousand registered users. With this large editorship, the Wikipedia undergoes about 2500 edits per day, with peak activity periods marked by around 6000 daily edits (http://www.Wikipedia.org/Wiki/Wikipedia:Statistics). As a result, the Wikipedia's size, three years after inception rivals that of the Encyclopedia Britannica (which contains about 85,000 entries and 55 Million words).

USER INTERFACE NEEDS

With Wiki capabilities proven, and the application base of Wikis growing, one stumbling block will be the comparatively poor user interface of Wiki applications. End users accustomed to word processors or at least web publication tools such as FrontPage will find the Wiki user interface too poor in its expressive capabilities. Furthermore many users will expect embedding of multimedia components as a feature. At present, although most non-text content is typically attached as a separate file, but it is not directly incorporated into the Wiki pages. Language limitations do not forbid more feature rich interfaces, although more complexity may challenge the goal of user interface simplicity. Figure 4 shows an editing screen for the TikiWiki with its limited formatting commands.

WIKI VERSUS WEBLOG (BLOG)

Wikis are far from being recognized as a serious knowledge management technology whereas, ovr the last few years, weblogs made significant in-roads and are now targeted as the next great conversational knowledge management technology [O'Shea, 2003]. While weblogs may soon be widely adopted, they have several conceptual limitations vis-à-vis Wikis, which shall be briefly outlined here.

Weblogs were conceived as an individual user technology, enabling users to quickly and easily publish their diaries on the web. As such, they are by-and-large an individual broadcasting technology, operating in one-to-many mode. With this communication pattern, they are well suited for a single expert who wishes to share his or her knowledge with a community, but less so for communal knowledge creation. Newer weblog technology permits multiple users and teams, as well as reader comments attached to weblog articles.

Individual ownership of weblogs offers advantages and disadvantages. Weblog owners can become famous (e.g., instapundit.com) and individually can draw considerable traffic. However, weblog traffic is distributed in log-normal fashion, with a few highly popular sites drawing a lot of traffic, while the majority barely rises above Internet noise [Kottke, 2003; Shirky, 2003]. Weblog proponents suggest using leading bloggers' star power to point to other useful weblog sites, and weblogs usually actively promote one another through hyperlinks.

Weblogs, being diaries, are organized chronologically. Newest posts usually come first, and older posts disappear in archives. This format is useful for news broadcasting, but not necessarily the best format to communicate knowledge. After all, the newest knowledge may not be the most relevant for the community at large. Many of today's weblogs compensate for this shortcoming with indexed archives, which are search engine friendly and enable the identification of knowledge by topic.

Weblogs might dominate Wikis on the issue of administration and technical platform needs. Being conceptually a single-user technology, multi-user access management, page version

management, or access tracking is little needed. Furthermore, weblogs do not necessarily need database backing but are frequently stored as flat files. Nevertheless, an organization that seeks to use weblogs at larger scale as a vehicle for knowledge management will have to be prepared to invest in infrastructure and administration, so as to maintain a stable knowledge management system. The value of the knowledge (or the cost to compile it) should quickly outweigh the value of the technology itself.

In summary, especially in a multi-user environment, weblogs have several shortcomings compared to Wikis and few comparable strengths. Furthermore, the way in which these weaknesses are addressed with newer weblog technology, results in weblog implementations that more and more resemble Wikis. Hence, we expect that ultimately weblogs and Wikis will merge into a single technology, differentiated largely by the definition of its authoring rightsand indexing methods. In that case, we should expect, however, that the key benefits will only arise once this technology takes advantage of community knowledge and the community's ability to correct any problems, rather than from individual user knowledge.

USE IN ORGANIZATIONS

Application Areas

Figure 1 identified the target application area of Wikis as ad-hoc problems in a distributed knowledge environment. For example, R&D teams working jointly on a new design while being spread over multiple sites may find the use of a Wiki highly beneficial. Similarly, a group of troubleshooters analyzing product failures at multiple locations may also benefit from the fast aggregation of knowledge (e.g., [Totty, 2004]). Once the knowledge stabilizes, it can remain in the Wiki, but does not have to. Some Wiki software implementations (e.g., Tikiwiki) enable the export ("dump") of a Wiki into a stand-alone set of web pages.

Application Limitation

Applications where Wikis are considerably less desirable are those with a stable and formalized set of knowledge that is not changed much by experiences. For example, a company's accounting policies may not benefit at all from being represented as a Wiki.

Architecture Limits

A possible hindrance to the rapid adoption of Wikis is the relative instability of their architecture. Many Wiki software packages are currently under development as open source, with frequent updates, bug patches, and new version releases. Organizations may not want to use such comparatively unstable platforms, or entrust them with significant volumes of corporate knowledge [Totty, 2004]. Organizations may at least require an administrator to manage the Wiki and the software version management, thus adding to the overhead of using this technology.

Knowledge Paradigm

One likely additional stumbling blocks for Wiki application is their unconventional knowledge creation and sharing paradigm. In many organizations, the Intranet represents the organization's official channel, with well-defined policies, procedures, and positions, and top-down information dissemination. If such a top-down, hierarchical culture of information sharing prevails, Wikis would have little chance to find their way into the organization, let alone to impact the knowledge creation and sharing process. The technology alone cannot be expected to change organization culture, without the organization's readiness and decision to use a more even approach to knowledge creation. This lesson was learnt over a decade ago in the use of GDSS, which "democratized" group meetings and led to more efficient idea generation, but also often resulted in clashes between group participants [Davison and Vogel, 2000; Briggs et al., 1999]. This issue, reverberated in the 7th Thesis from the Cluetrain Manifesto [Locke et al., 2000]: "hyperlinks subvert hierarchy", is also likely to hold back Wiki application in organizations with strict hierarchies and high power distance.

V. CONCLUSIONS

In the present day environment, where technologies come and go very quickly, one key issue is the relevance and value of any particular technology. Hence part of the purpose of this article was to find an answer to the questions “do Wikis matter”, and “why do Wikis matter”?

The Wiki structure, functionality, and application—as in the Wikipedia—offer several supporting arguments. Wiki technology enables collaboration of people similar to open source software development, while at the same time minimizing the effort of content publication.

Since the majority of organizational knowledge is still largely kept solely by people, they are the source of much of relevant organizational knowledge. Instead of trying to automate knowledge creation we have to create tools that make it simple for people to express, share, and find knowledge. This is what Wikis do. They harness the power of many and provide a dynamic that lets people volunteer to create a common good (whose mechanisms we don’t yet fully understand). As a result, we should expect faster knowledge management with fewer mistakes than in “closed source” knowledge management environments. The impressive statistics of the Wikipedia, its content, growth, and maintenance activity, give initial evidence for the potential of Wikis.

RESEARCH

Wikis offer an opportunity for much useful research, targeting at least three directions.

- *Technology focused* research should explore ways to augment Wiki technology so as to enable more formal knowledge representations, and ideally to facilitate the transformation from less into more formal knowledge representations. Furthermore, user interface improvements are much needed to augment the look and feel of the interface, while maintaining ease and speed of content creation and publication.

- *Development methodology focused* research could explore effective methodologies for knowledge creation, acquisition, and representation within Wikis, thus giving users prescriptions on how best to record their knowledge and combine the knowledge from multiple users. Analogous to the guidelines for extreme programming, such research may define guidelines for “extreme knowledge acquisition” to improve Wiki effectiveness.

- *Measurement of user motivation and performance* in collaborative knowledge management environments. This research could assess knowledge development speed, accuracy, and similar quantitative measures, but also assess people’s motivations with respect to Wiki (or other collaborative technology) use. In this context, a comparative evaluation against other knowledge management technologies appears especially valuable.

SUMMARY

Overall, Wikis are a promising technology, which appears highly relevant to today’s knowledge work, and is particularly interesting because of the paradigm shift in knowledge creation and sharing it requires. Understanding this technology at the application level and from a research perspective should be highly rewarding.

ACKNOWLEDGEMENT

The work described in this paper was partially supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China [Project No. CityU 1151/02H].

Editor’s Note: This article was received on October 12, 2003. It was with the author for 3 months for 1 revision. It was published on March 31, 2004.

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EDITOR'S NOTE: The following reference list contains the address of World Wide Web pages. Readers who have the ability to access the Web directly from their computer or are reading the paper on the Web, can gain direct access to these references. Readers are warned, however, that

1. these links existed as of the date of publication but are not guaranteed to be working thereafter.
2. the contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.
3. the authors of the Web pages, not CAIS, are responsible for the accuracy of their content.
4. the author of this article, not CAIS, is responsible for the accuracy of the URL and version information.

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Communications of the Association for Information Systems

ISSN: 1529-3181