CHAPTER

INTERFACE DESIGN AND EVALUATION

7

FOUNDATIONS FOR INTERFACE DESIGN AND DESIGN PRINCIPLES

FOUNDATIONS FOR INTERFACE DESIGN

The information retrieval (IR) process is an interaction process between users and IR systems. In a digital library environment, interface design needs to facilitate the interactions between users and digital libraries. Saracevic's (1996, 1997) stratified interaction model highlights the interface (the platform for exchange) in which the interactions between users and systems take place. According to Ingwersen and Jarvelin's (2005) integrated IS&R Research Framework, the interaction process can be further considered as the interactions among cognitive actors of all the stakeholders in the information retrieval and seeking process, which consist of the following human groups in the information creation, organization, dissemination, use process as well as interface design and retrieval engine design:

- Creators of information objects
- Indexers constructing representations of information objects to facilitate retrieval of information objects
- Designers creating interfaces to facilitate users' interaction with systems
- Designers building retrieval engines and algorithms to facilitate users' effective information retrieval
- Gatekeepers determining the availability of information objects into a collection
- Information seekers or searchers looking for information to accomplish their tasks
- Dommunities representing a variety of groups in different organizational, social, and cultural contexts

The critical challenge for interface design is how to offer an interface platform for users to interact with all the cognitive actors involved in the process. To be more specific, in Belkin's (1996) episode model of interaction with text, he proposes an approach that shows how interface design can support different types of interactions by supporting various types of information-seeking strategies.

DESIGN PRINCIPLES

General interface design principles also apply to digital library interface design. Nielsen (1995) proposes 10 detailed user-interface heuristics: visibility of system status; match between system and real work; user control and freedom; consistency and standards; error prevention; recognition rather than recall; flexibility and efficiency of use; aesthetic and minimalist design; help users recognize, diagnose, and recover from errors; and help and documentation. Shneiderman's (1998) eight golden rules of interface design are similar to Nielsen's interface heuristics. He does point out some unique design rules,

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such as offering informative feedback and permitting easy reversal of actions. Norman (2002) presents two principles of good design: (1) a conceptual model and (2) visibility. He specifies the following guidance for a good design:

- Visibility—Extremely important aspect of interface design; features should be obvious to aid users' awareness of their purpose.
- Mappings—Features should correspond to the perceived use.
- Affordances—The interface promotes understanding of how to use features.
- Constraints—Design should take into account the limitations of features.
- Conceptual model—Mental idea of a design element should be based on mappings, affordances, and constraints.
- Mental model—Users' actions interactions with features should relate to conceptual metaphors by which the users are already familiar.
- Feedback—Interface should make users aware of their use of features and the results of such use.

These guidelines can serve as general design principles for digital library interface design. More importantly, digital library interface design needs to have its own unique characteristics.

ITERATIVE DESIGN

Digital library interface design cannot be done in one step. It is an iterative design process that moves from design to evaluation, to redesign and reevaluation, back to redesign again, and so on. The most important step in developing a digital library is to identify the audience and its information needs as well as to understand the iterative design process (Norberg et al., 2005). Somerville and Brar (2009) discuss the methodologies for studying user needs in a user-centered approach: interviews, focus groups, ethnographic studies, and observation. They place an emphasis on iterative design from prototyping to evaluation, modification, and implementation. Nielsen (1993) recommends at least three rounds of iteratively designing an interface based on user testing.

The iterative design process is an effective approach for digital library design. Norberg et al. (2005) discuss their redesign process of a digital library based on usability testing and focus groups. Prototypes of redesigns were presented to each focus group for its feedback. The feedback was incorporated into each successive redesign of the digital library. The redesign process was an iterative and participatory process involving the key stakeholders of the digital library. They conclude that users' interactions with digital libraries are task oriented and context dependent. Based mainly on the direct observation and interviews, Ferreira and Pithan (2005) report on the usability study integrating HCI principles and information search processes revealing issues in the design. Further improvements of the digital library are suggested.

Iterative design is closely associated with iterative user-centered evaluation. Bertot et al. (2006) focus on the functionality, usability, and accessibility of iterative digital library assessment. Functionality assesses whether a digital library enables users to perform desired operations. Suggested criteria include the ability to refine searches and the ability to apply a variety of search options. Usability assesses whether a digital library enables users to use different features of the digital library, which include navigation, content presentation, labels, and search process. Accessibility assesses whether a digital library enables users with disabilities to access the digital library, dealing with factors such as alternative forms of content, color independent, clear navigation mechanisms, and table transformation.

DESIGN AND CUSTOMIZATION OF USER INTERFACE

The process of designing and implementing a user interface consists of the following steps.

CONCEPTUAL DESIGN: IDENTIFICATION OF USERS' UNIQUE NEEDS

The design of a user interface first needs to consider what users want. Phillips (2012) proposes to address the following questions:

- Who will use the interface?
- What can be done with the interface, and what are its limitations?
- Where will the interface be used?
- Why will users use the interface?
- How will the interface be used?

In order to characterize the user behavior, here are the main questions that need to be answered:

- How does the interface encourage or discourage users' tasks?
- How are information search features designed to facilitate user tasks?
- How do users employ information relative to the larger information setting?
- How do users search tactics promote task completion, and do these tactics remain constant throughout the task?
- How do users understand, save, and use data, and what features are they using to do so?
- How do users determine success?

Different types of users have different requirements. Chapter 8 discusses in detail the needs of different types of users. Digital library interface design needs to tailor to specific user needs. Children are one specific type of user group. Here is one example of how to convert children's needs into an interface design. Kaplan et al. (2004) include children as partners to prototype, test, and develop digital libraries. The following questions were examined:

- What do the concepts reading and library mean to children in this age group?
- How do American tweens and teens read in their everyday lives? What are its uses and rewards for them?
- How do their knowledge about digital technologies and their experiences with computers and the Internet shape their expectations of online texts? (pp. 90–91).

In addition to the six children on the design team, they also solicited opinions from 40 children for contextual inquiry. Observation, note-taking, and interview methods were used to collect data when children engaged in the following tasks: locating reading materials in public libraries, reading for pleasure at home, working on reading assignments at home, and working on reading assignments as part of the class work in a public library. A sticky notes session, brainstorming, and prototyping were applied to develop the user interface for children.

Simultaneously, the design of interface also has been taken into consideration for the types of digital libraries. Users exhibit different types of strategies in searching musical and video digital libraries. Based on an ethnographic study consisting of interviews, focus groups, and observations, Cunningham et al. (2003)

identify the following music information-seeking strategies for the design of a music digital library: known item, significant browsing activity, collaborative music shopping, useful journal run strategy, keeping up to date, visual music shopping, and reluctance to ask for help. These behaviors are not well supported by the current musical digital libraries. The following suggestions for interface design are made: (1) serendipitous browsing by offering CD covers accompanied by snippets of songs from each album; and (2) genre browsing supported by similarities of sound or rhythm.

Let us examine three examples of digital libraries development: a digital musical library, a children's digital library, and a video digital library. In establishing a digital musical library test bed system, the main user interface components were first proposed, consisting of search window, audio player, playlist, timeliner, score viewer, and bookmark editor. Associated functionality was also defined. For example, the functionality of a search window was specified as "using a metadata model designed specifically for cataloging and finding classical and popular music. The search window lets user input such music-specific criteria as composer, performer, work, and key. The search results present, for example, all the performances of a particular work, along with information about performers so that users can pick out the performance of interest" (Notess et al., 2005, p. 302).

In building an international children's digital library, Druin (2005) reports a more intensive design study with children. Children from age 7–11 were selected to participate. On average, they stayed with the project for two years. Adult and children researchers worked together twice a week during the school year and intensive weeks over the summer. The International Children's Digital Library interface was developed based on the following methods: children interviewing other children, writing one thing a child likes and dislikes, group discussion sessions, and prototypes to sketch new ideas. The associated features that were implemented are search categories, feelings, colors, customizable good reader colors, and spiral book reader.

Focusing on the video content, Albertson (2013) proposes an interaction and interface design framework for video digital libraries. The key for the conceptual design is associating user requirements with the interface design. The uniqueness of the framework is that it maps the conceptual understanding of the users' interaction with video digital libraries to the design of user interfaces. He created two figures to illustrate the conversion. While Fig. 7.1 specifies user interaction components of the framework, Fig. 7.2 suggests interface design components of the framework. In both figures, the user and situation are the main dimensions of the interactive video retrieval process. User factors represent different levels of experience, knowledge, and domain affiliation, which are presented vertically from a low level (bottom of the figure) to a high level (top of the figure). Situational factors represent system support and/or barriers, which are presented horizontally from high situational support (left) to low levels of support (right). The third dimension is related to the user interaction and its associated interface designs/features. Undoubtedly, user interaction and interface design are dependent on the user and situational factors. Interface design closely corresponds to user interaction. The size variation distinguishes the differences from broad to specific concepts, and the center section highlights the core of the framework. The main contribution of this framework is that it connects user interaction to system supportive features.

PROTOTYPE DESIGN

As part of the iterative design, prototype design is a quick and flexible approach for the developers to solicit feedback from users and stakeholders. It simulates part or all of a user interface by drawing it

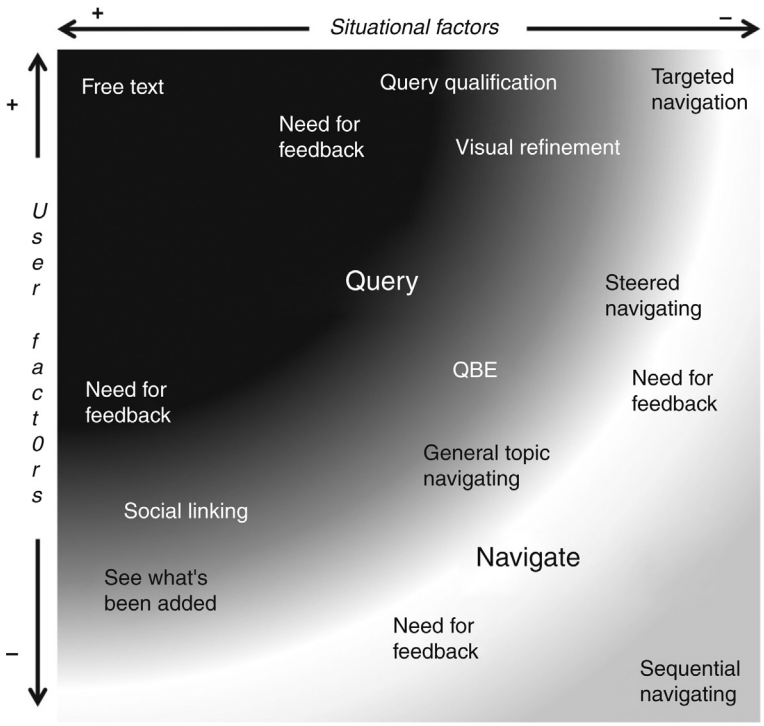

FIGURE 7.1 User Interaction Component of Framework (Albertson, 2013, p. 677)

out using paper and pen or a different tool. Hackos and Redish (1998) provide main components to include in prototypes:

- The overall architecture of the interface
- Visual depiction of main screen layout
- Visual depictions of secondary screens
- Visual depictions of the primary features
- Alternate design concepts

Wagner (1990) discusses the advantages of how a prototype enables designers to present design ideas more efficiently and can easily modify their designs based on the feedback. Most prototype design ideas are sketched on paper. There are also tools used to facilitate prototype design. Electronic tools can recognize widgets and widget behaviors, unlike paper prototypes' static images. For example, researchers developed the electronic Sketching Interfaces Like Krazy (SILK) to allow designers more flexibility in creating and evaluating design prototypes. SILK shows interface elements or widgets' behaviors and supports the creation of storyboards (Landay and Myers, 2001).

A good digital library design takes several rounds of prototype design and assessment. Norberg et al. (2005) report their development and testing of prototypes of user interfaces in a digital library via a series of focus groups. The focus groups were presented with the original site and prototype redesigns.

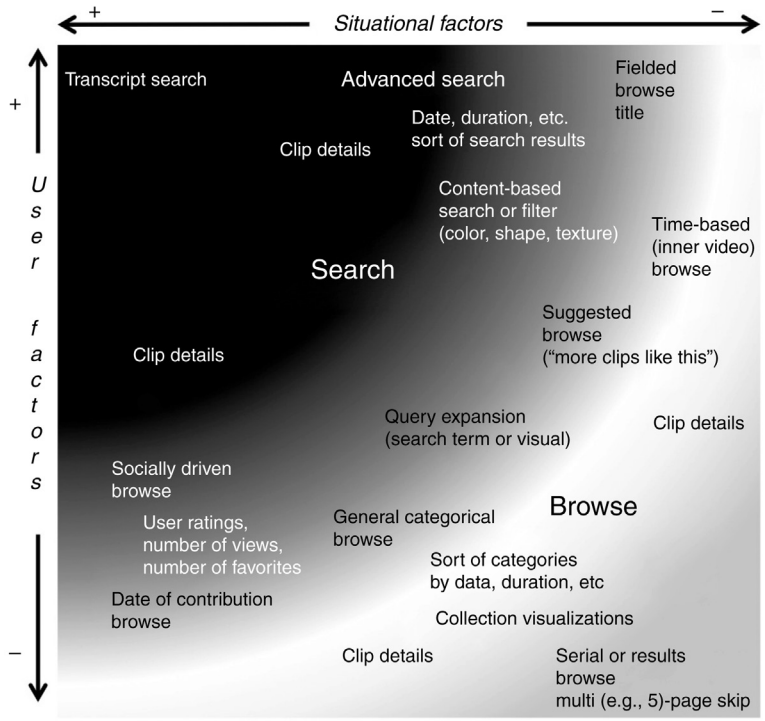

FIGURE 7.2 Interface Design Component of Framework (Albertson, 2013, p. 677)

Open-ended questions were asked to solicit feedback for different ideas of prototype designs. Several rounds of prototype design took place ranging from changing the color scheme to fonts or position of elements. During the prototype tests, users participated in the iterative design process. Somerville and Brar (2009) describe another example of user-centered design for digital library projects. Students were involved in investigating their peers' information-seeking needs. Their findings led to the creation of paper prototypes and usability tests. Positive user experiences are important to incorporate into the digital library projects.

Prototype design is also a great approach for the design of children's digital libraries. Prototype design allows children to view examples of designs in different formats. Children were shown a web-based mock-up of the three interface designs of a children's digital library. After dividing children into several groups, they were give a paper-based version of the three interface designs for more careful examination. They were instructed to write down three things they liked and three they desired for the digital library interfaces. The results show that they prefer the use of bright colors, good graphics, and audio (Theng et al., 2000). Prototype design is also employed for visualization design for digital libraries. Using paper-based prototyping, users worked in pairs to sketch design ideas in visualization form for the given scenario. After presenting the initial ideas, the group collaborated to develop the final prototypes. The study demonstrates that it is beneficial to include users and other stakeholders in the design of digital libraries (Zaphiris, 2004).

INTERFACE DESIGN: CONFIGURATIONS

Digital library interface design has to consider both the needs of users and characteristics of digital collections. Among all the interface components, features to support collection selection, query formulation, results manipulation and evaluation, and help use are vital for digital library interface design. Chowdhury (2004) summarizes the design components of digital libraries:

- Interface features:
  - types of interface including simple and advanced search interface
  - languages of the interface
  - navigation options, shortcuts, and system information
  - screen features including colors, typography, layout, and graphics
  - personalization of the interface
- Resource selection
- Query formulation
- Results manipulation
- Help

There are multiple digital library content management systems available to design these interfaces. Detailed discussion of these systems are shown in Chapter 6. Each content management system has its own tutorials for its interface design. As CONTENTdm is one of the most popularly used systems, Table 7.1 presents the configuration options of the interface for a collection built with CONTENTdm.

Not all digital library systems apply the same approach to interface configuration. Omeka uses themes to customize the look and feel of the public Omeka site. Themes are a collection of template files and help functions that use data in each specific Omeka archive and display those data to end users. From the administration side, designers can control some of that display through configurations. In versions 1.3 and above, all themes are configurable in the Settings > Themes admin screen.

Configurations are unique for each theme and will be saved with the theme. Each theme must be configured when changing designs. Upon returning to the original theme, all of the initial configurations will be saved. The configuration includes the look of the digital library site, navigation, featured elements, homepage text, and metadata displayed (Omeka, 2015).

- Choose a logo file. Designers can use their own logo file. Recommended maximum width is also suggested.
- Custom Header Navigation. Designers are allowed to create their own theme header with corresponding text.
- Display Featured Item. Designers can show a featured item on the homepage.
- Display Featured Collection. Designers can show a link featuring a collection on the homepage.
- Display Featured Exhibit. Designers can show a link featuring an exhibit on the homepage.
- Homepage Recent Items. Designers can choose the number of recent items to be displayed on the homepage.
- Homepage Text. Designers can add brief text to be displayed on the homepage.
- Footer Text. Designers can add text to be displayed in a theme's footer. This can be a good place to add credits or links to funders, such as credits information.
- Display Copyright in Footer. Designers can display copyright information in the footer (para. 5).

Table 7.1 Configuration Options Offered by CONTENTdm (Configuring, n.d., p. 3)

Quick Config[a]	An optional way to set up some initial global configurations that help establish the site identity.
Appearance	Use the Appearance configurations to tailor the look and feel of your Web site or collections by modifying the header and setting fonts and colors to reflect your branding.
Searching and Browsing	Use the Searching and Browsing options to configure the default search mode and advanced search scope and to configure the results page display, default sorting, and more.
UI Widgets	Use the UI Widgets configurations to enable and define features that can help users explore and experience items in your collections. For example, create Suggested Topics, which guide end users in their research, and tailor the QuickView display, which helps users quickly scan items with some additional detail.
Image Viewer	Use the Image Viewer configurations to tailor toolbar options and other features to best showcase items in your collections.
Navigation	Use the Navigation configurations to edit or add to the header and footer navigation links.
Items	Use the Items configurations to set various options that are available when end users view items in your collections. For example, manage user-generated content, enable and configure the Share and Reference URL features, choose whether to display the full text for items with transcripts, and configure metadata display settings.
Page Types	Use the Page Types configurations to edit the contents and set representative item display options for key pages of your Web site, optionally replace key pages with custom pages, enable your site for RSS, and define the display of compound objects and PDF files.
Tools	Use the Tools option to configure the localized version of your Web site interface text, including the default language, uploading a custom language file, and enabling users to select from multiple languages. You also can configure a CONTENTdm Log In/Out link on your Web site, and configure the credentials used by a custom form for end-user content submission.
Custom Pages/ Scripts	Use the Custom Pages/Scripts options to add additional pages to your Web site and use your own JavaScript scripts and CSS to modify the Web site behavior and appearance.

[a]*For this class you should not see the Quick Config option. If you can, please do not use it as it will alter the settings for the entire class website.*

The earlier two examples illustrate interface configurations from a commercial digital library content management system and an open source system. Both CONTENTdm and Omeka have rather limited options for interface configuration. Each content management system has its own options and instructions. Chapter 6 offers more detailed discussions on the main digital library content management systems.

CUSTOMIZED DESIGN AND VISUAL TOOLS

Each digital library has its own unique content and unique user groups. It is essential for the interface to reflect the uniqueness of the theme of the digital library or collection. Content management systems in general allow customization of digital library interface. Here is one example from UWM Libraries' Digital Collections (http://collections.lib.uwm.edu/). UWM Digital Collections are built using CONTENTdm, which provides an open application programming interface (API). CONTENTdm APIs enable developers to customize the layout and integrate various features into a digital library interface. In particular, it is possible to integrate different features into an interface by connecting

collections through APIs provided by the digital library system, although the customization is limited, and integrating applications requires quite a bit of programming.

The timeline view collection application was successfully added to the UWM digital library site (Fig. 7.3), and the application accessed the metadata organized in a JSON file to display the content of the selected collections. The Web page in Fig. 7.3 displays a collection of items related to March On Milwaukee. The items are organized into sections arranged chronologically. Each section header describes an historical event and its timeline, followed by a short description of the event, and a link to a file presenting the event in detail. There are various resources including images, video, and audio. The timeline application was also implemented in other digital library software, such as Omeka (omeka.org) (Fig. 7.4). The image was created by Sukjin You by using and revising the following timeline open source code to the Omeka system: https://timeline.knightlab.com/; https://github.com/NUKnightLab/TimelineJS. It proved that the timeline application can be implemented in different digital library platforms that provide an option for embedding customized pages or allow access to the content.

Visualization is an approach applied quite popularly in digital libraries. Developers can design their own visual tools to facilitate users' effective interaction with digital libraries. Many digital libraries have incorporated visual tools into the interface design. Fig. 7.5 shows the map from the Digital Public Library of America. Users can select digital objects from different states. When a circle on the map is clicked, the titles of digital objects and thumbnails are displayed. Visualizing query and search results is the most applied application of visual tools. Linn et al. (2007) introduce the SearchGraph that enables users to view abstract visualization of search results. Moreover, users can manipulate the display, and use sort and filter options to view the search results from different perspectives. Seifert (2011)

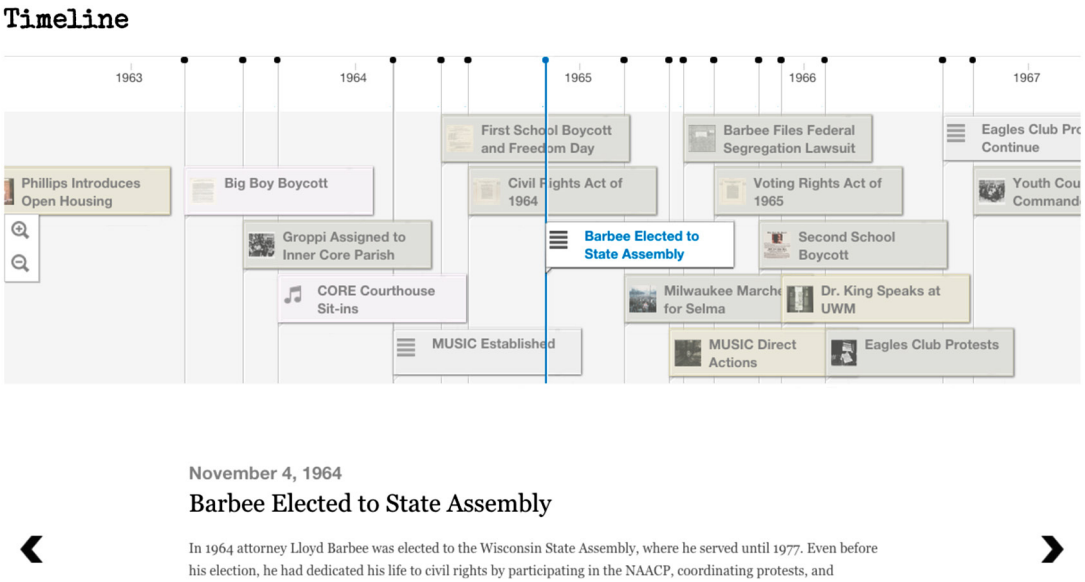

FIGURE 7.3 Implementation of the Timeline Application in the University of Wisconsin-Milwaukee Digital Collection "March on Milwaukee" Built in CONTENTdm

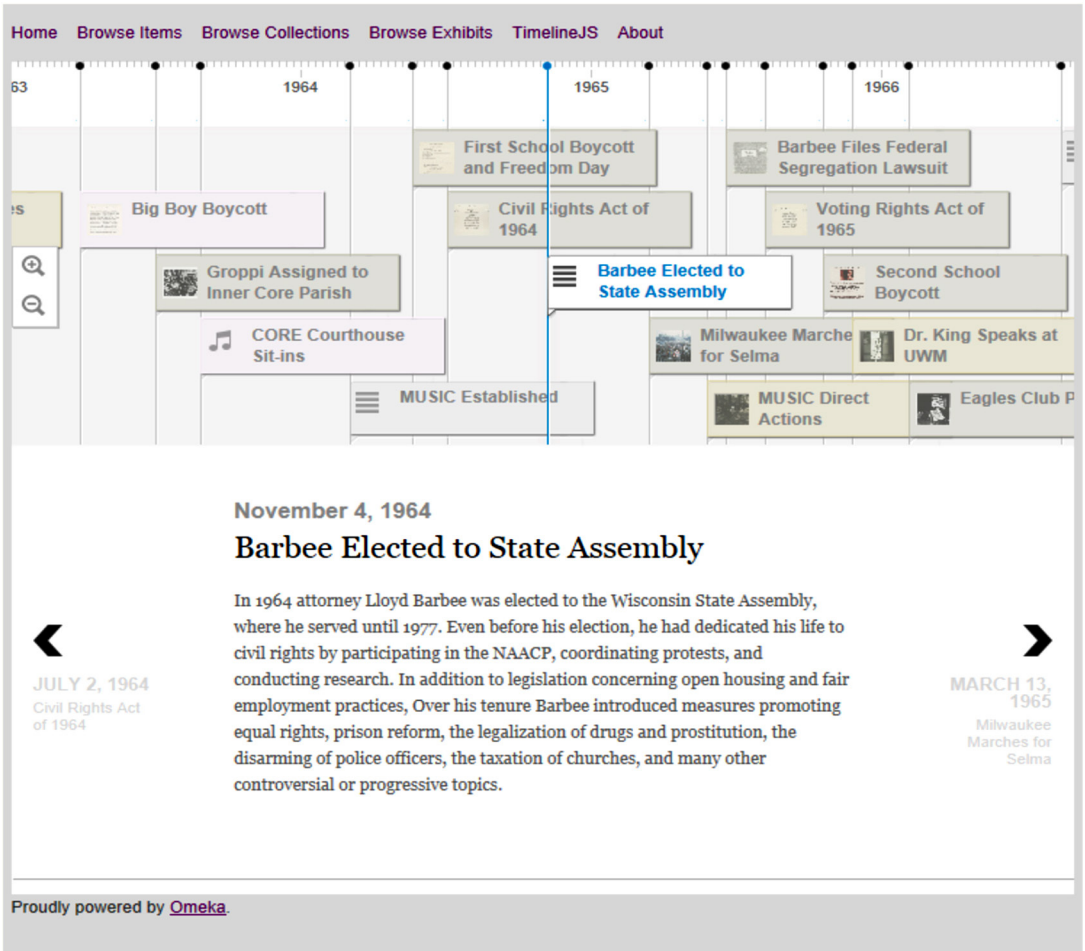

FIGURE 7.4 Example of a Timeline Developed for Omeka by Sukjin You

With permission from Sukjin You (University of Wisconsin–Milwaukee).

proposes an interactive multidimensional query visualization tool for users to manipulate queries to retrieve relevant results under different subtopics in digital libraries. Van Hoek and Mayr (2013) provide an overview of visualization applications in supporting the search process in digital libraries. Examples include VQuery that visualizes the query and assists users to specify queries using Boolean operators; INVISQUE system that integrates the division between query specification and results; InfoSyk that contains a hierarchical tree browser and a star map providing a good overview of documents; The Cat-A-Cone system that is an early 3-dimensional system that uses cone trees to display category hierarchies; and the 3-dimensional search interface NIRVE system that connects user query terms to concepts.

In contrast to searching, browsing is a unique component for digital libraries. Rajkumar (2006) designed a visual browsing interface that offered users the opportunity to navigate through the records of a digital library with multidimensional, hierarchical, and categorical data. The visual interface was

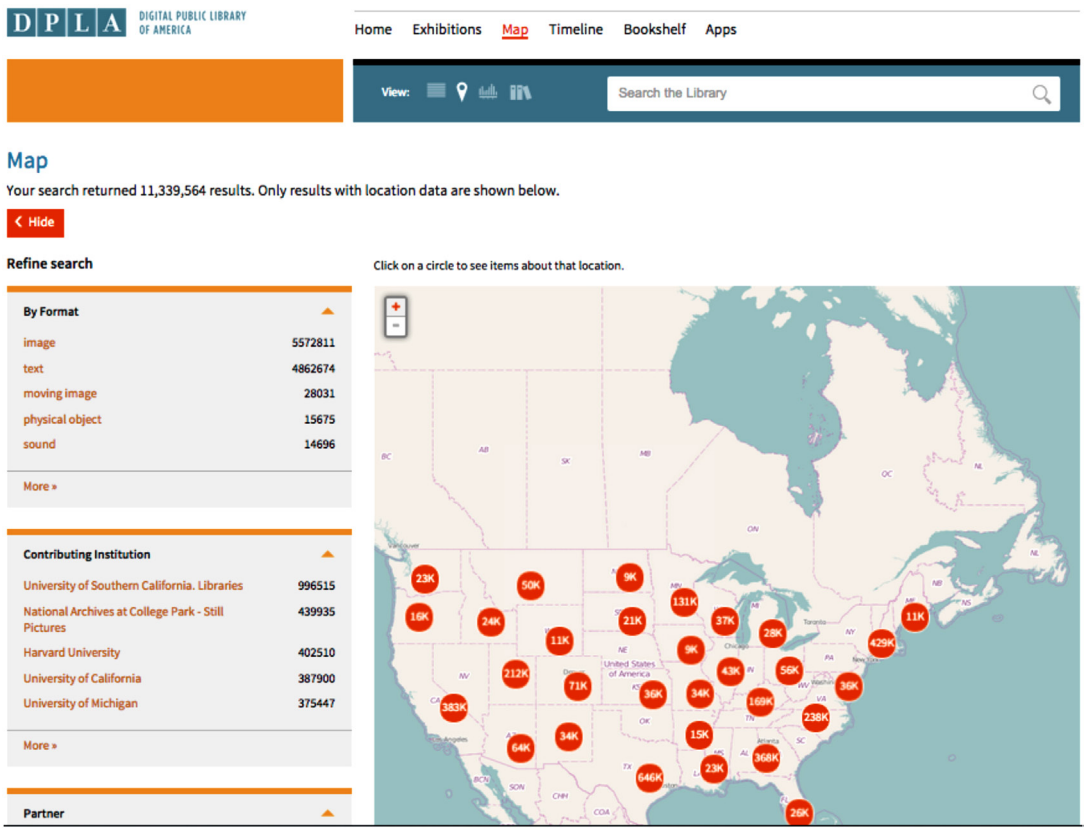

FIGURE 7.5 Interactive Map of the Digital Public Library of America

designed following three principles: consider browsing structure as the primary data, display all possible browsable dimensions, and treat dimensions uniformly.

Metadata has been used to improve the design of visual interfaces in digital libraries. Shiri (2008) examined 21 metadata-enhanced digital library visual interfaces, in particular their visualization techniques and metaphors. Types of metaphors implemented include treemaps, timelines, scatter plots, Venn diagrams, charts, sematic-spatial maps, and association networks metadata. He points out that visualization techniques and metaphors become an effective approach to support users exploring information in digital libraries. In addition, ActiveGraph is a visualization tool that enables users to view and customize content of a digital library by adding or editing metadata (Marks et al., 2005).

USABILITY TESTING

The objective of digital library evaluation is to assess to what extent it meets its objectives and offer suggestions for enhancements. Citing human computer interaction research, Shneiderman (1998) discusses human computer interaction/interface evaluation criteria: usability, functionality, effort, as well as task appropriateness and failures.

Usability testing is a critical component of user-centered design and an approach for improving user interface. Easy to understand and easy to use are the keys to usability of a user interface. Usability of a digital library is associated with its accessibility, in particular how easily users can interact with the interface of the digital library (Chowdhury et al., 2006). Accepted definitions of usability have been focused on multiple attributes:

- Learnability—How easy is it for users to perform tasks when first interacting with the design?
- Efficiency—How quickly can users perform tasks?
- Memorability—How can users refresh their interactions with the design after not using it for a while?
- Errors—How many errors do users make? How easily can they recover from errors?
- Satisfaction—How content are users with the design? (Nielsen, 1993).

Usability is also extended to other measures, such as efficiency of interactions, avoidance of user errors, and the ability of users to achieve their goals, affective aspects, and the search context (Blandford and Buchanan, 2002). Blandford and Buchanan (2003) also examine the classical usability attributes and they suggest adopting many of these attributes to the evaluation of digital libraries. Some of them, such as learnability, need to be modified because users treat the library system as a tool, not as an object of study. They are more concerned with building a user perspective into the design cycle than with the final evaluation.

Two approaches have been applied to usability studies: empirical testing with users and analytical analysis with usability experts (Chowdhury et al., 2006). Nielsen (1994) summarizes the following usability methods:

- Heuristic evaluation: Having usability experts evaluate each element in accordance with usability principles.
- Cognitive walk-throughs: A step-by-step process simulating a user task.
- Formal usability inspections: Combination of heuristics evaluation and cognitive walk-through.
- Pluralistic walk-throughs: Similar to cognitive walk-through, but conducted in a group setting with users, developers, and usability experts discussing the steps of the walk-through together.
- Feature inspection: Assessing a proposed feature set to see whether it is natural for users to use and does not require extensive knowledge/skills to use the set.
- Consistency inspection: External designers checking an interface to see whether the new design operates in a similar fashion to other designs.
- Standards inspection: Inspecting the interface for compliance with standards by an expert.

In the context of digital libraries, Bertot et al. (2006) suggest some important questions for the usability testing that help the enhancement of the digital libraries:

- Were the basic navigation identification tasks intuitive?
- Were data presented within each interface logical, clear, and easy to understand?
- Did each interface perform as users expected it would?
- Could the data obtained from the testing be useful?
- What are some specific recommendations to make each interface more useful?
- What are some specific recommendations to improve each interface? (pp. 22–23).

A pilot study is essential for usability testing. Notess et al. (2005) identify several issues that a pilot study can help resolve, including the design of test tasks, system bugs, rewording of the tasks, etc.

USABILITY TESTING: CRITERIA AND APPROACHES

According to Liew's (2009) review article on organizational and people issues in digital library research, use/usability issues account for the majority of the work. Among the use/usability category, most of the papers focus on usability. Jeng (2005a, b) concludes that usability is a multidimensional construct. She further proposes an evaluation model for the assessment of the usability of digital libraries by examining their effectiveness, efficiency, satisfaction, and learnability. User satisfaction is a complicated construct that covers ease of use, organization of information, labeling, visual appearance, content, and error correction. The evaluation model was tested, and the results revealed that effectiveness, efficiency, and satisfaction are interrelated. Dillon (1999) develops a qualitative framework (termed TIME) for designers and implementers to evaluate the usability of digital libraries which focuses on user task (T), information model (I), manipulation facilities (M), and the ergonomic variables (E). Buttenfield (1999) suggests two evaluation strategies for usability studies of digital libraries: the convergent method paradigm that applies the system lifecycle into the evaluation process and the double-loop paradigm that enables evaluators to identify the value of a particular evaluation method under different situations. Even though usability is widely discussed, it is important to characterize the uniqueness of usability attributes for the assessment of digital libraries.

Before conducting usability testing, researchers have to make decisions regarding the selection of appropriate usability criteria. Design elements are one of the popular components of usability studies, which is essential for interface enhancement. Van House et al. (1996) focus on query form, fields, instructions, results displays, and formats of images and texts in the iterative design process for the University of California Berkeley Electronic Environmental Library Project. After reviewing literature on digital library user interface, Hariri and Norouzi (2011) identify the top 10 evaluation criteria for digital library interface: navigation, searching, design, guidance, error management, presentation, learnability, user control, consistency, and language. These criteria match pretty well with Nielsen's (1995) 10 interface heuristics.

Comparison of two user interfaces is a popular approach for conducting usability studies and offer useful design recommendations for digital library designers. Miller et al. (2012) compare the usability of the interfaces of the Open Library, Google Books, and HathiTrust on aesthetics, usability, and main interface components. Subjects first evaluated the aesthetics of the interfaces based on Lavie and Tractinsky's (2004) measures on aesthetic, being pleasant, clear, and clean. Next, subjects were instructed to evaluate the usability of three interfaces by adopting McGee et al. (2004) and Flanagin and Metzger's (2003) 10 items: "the extent to which interfaces were consistent and efficient, organized, easy and intuitive, effective, useful, controllable, complete and sophisticated, professional, trustworthy, and reliable" (p. 367). In addition, the following interface components were assessed: "collection browse, collection search, viewer navigation, viewer options, output options, accessibility, and help features" (p. 367). The findings indicate that most of the subjects preferred the Open Library for its aesthetic and large elements within its interface, as well as for presenting elements in a similar fashion to their counterparts in the physical library. Users like the familiarity of Google Books' Google-based interface. Interestingly, too many options are not welcomed by users. For that reason, the interface of HathiTrust is considered too complicated.

Some usability studies examine specific designs or features for interfaces, such as the organization approaches of digital libraries. Meyyappan et al. (2004) measure the effectiveness and usefulness of the alphabetic, subject category, and task-based organization approaches in a digital library, and the results show that the task-based approach takes the least time in locating information resources. By applying

usability and affordance strength questionnaires, interviews, think-alouds, and observations, Shiri et al. (2013) examine the main elements of two user interfaces consisting of multilingual features, thesaurus and search functions, and visualization and visual appeal. Users prefer an integrated interface that connects thesaurus, query, and document spaces together. Ease of use of multilingual features, thesaurus, and search functions are the main reasons for users' liking of one of the interfaces.

Usability studies of digital libraries are often performed as a collection of studies across time. In Cherry and Duff's (2002) longitudinal study of a digital library collection, they focus on how the digital library is used and the level of user satisfaction with response time, browse capabilities, the comprehensiveness of the collection, print function, search capabilities, and the display of document pages. Hill et al. (2000) tested user interfaces of the Alexandria Digital Library (ADL) through a series of studies. The following usability requirements were derived from user evaluations: a unified and simplified search, being able to manage sessions, more options for results display, offering user workspace, holdings visualization, offering more Help functions, allowing easy data distribution, and informing users of the process status. Bertot et al. (2006) adopt a broad understanding of usability, including satisfaction, in addition to ease of use, efficiency, and memorability in the iterative evaluation of the Florida Electronic Library. They also bring in functionality and accessibility as major digital library evaluation criteria.

Interaction between users and digital libraries is also an important component for usability testing. Budhu and Coleman (2002) highlight the key attributes of interactivities: reciprocity, feedback, immediacy, relevancy, synchronicity, choice, immersion, play, flow, multidimensionality, and control. They evaluate interactivities in a digital library with regard to multiple aspects including interactivities in interface. Thong et al. (2002) identify the determinants of user acceptance of digital libraries, and among them, perceived usefulness and ease of use are the major factors that can be predicted by the interface characteristics (terminology clarity, screen design, and navigation clarity), organizational context (relevance and system visibility), and individual differences (computer self-efficacy, computer experience, and domain knowledge).

USABILITY TESTING: SPECIFIC DIGITAL LIBRARIES AND SPECIFIC USERS

Some researchers concentrate on specific digital libraries and specific users, in particular, educational digital libraries and learners. Focusing on digital libraries for teaching and learning, Borgman et al. (2000) conducted formative evaluation in formulating design requirements and summative evaluation in judging learning outcomes. Yang (2001) examined learners' problem solving process in using the Perseus digital library by adopting an interpretive and situated approach. The findings of the study help designers develop and refine better intellectual tools to facilitate learners' performance. Kassim and Kochtanek (2003) performed usability studies of an educational digital library in order to understand the user needs, find problems, identify desired features, and assess overall user satisfaction.

Children have very unique interaction characteristics as users of digital libraries. As design partners, children show preference to a simple interface with unique characteristics, such as bright colors and images, and audio (Theng et al., 2000). Bilal and Bachir (2007a, b) investigated the interaction of 10 Arabic-speaking children with the ICDL to find Arabic books resulting from four tasks. Individual interviews, group interviews, and log analysis were employed to collect data. The findings offer suggestions for the improvement of ICDL. Younger children have difficulty understanding all the representations of the ICDL. A simple visual interface with meaningful icons and audio capabilities assists international

children in effectively seeking information in ICDL. Well-designed icons for the text-based browse and search functions are essential for the children without much knowledge of English. An Arabic version of the ICDL that supports keyword searching in Arabic is also requested. A drawing and coloring feature for children to express feelings, thoughts, and perceptions is also desired.

Based on children's interaction with IR systems at home, Druin et al. (2010) identify seven search roles that children play: developing searcher, domain-specific searcher, power searcher, nonmotivated searcher, distracted searcher, visual searchers, and rule-bound searcher. Even though this study is not designed specifically in a digital library environment, their findings are applicable for improving the digital library interface design. They further offer interface design implications for children:

- Support multiple search roles
- Learn from power searchers to support other searcher roles
- Overcome known barriers
- Design interface to attract children to search
- Use the interface to have positive impact

Martens (2012) stresses that four areas need to be taken into consideration when designing interfaces for children:

- Children's unique developing cognitive and motor skills
- Children with different ages requiring different designs
- Classification, hierarchies, and metadata need to be age appropriate
- Social components, such as graphics and interactive and personalization features, need to be attractive to children.

Another specific group of users is people with disabilities. The discussion of how to design for people with disabilities is in the latter section of this chapter. The detailed discussion of different types of user groups and their needs and behaviors in interacting with digital libraries can be found in Chapter 8.

USER PERSPECTIVE AND ORGANIZATIONAL USABILITY

Some researchers solicit user perceptions regarding some of the digital library evaluation criteria. In Jeng's (2005a, b) study, the evaluation is designed to detect users' perceptions of ease of use, organization of information, terminology, attractiveness, and mistake recovery. For example, ease of use is considered "simple," "straightforward," "logical," "easy to look up things," and "placing common tasks upfront." Very few researchers have conducted digital library evaluation criteria studies from users' perspectives. Xie (2006) investigated digital library evaluation criteria based on users' input. Users developed and justified a set of essential criteria for the evaluation of digital libraries. At the same time, they were requested to evaluate digital libraries of their own selection by applying the criteria that they developed. After comparing evaluation criteria identified by the users and researchers, and criteria applied in previous studies, the author found that there was a commonality in the overall categories of the evaluation criteria. However, users place more emphasis on their own perspectives and less on the perspectives of developers and administrators. Users value the ease of use of the interface. Xie (2008) further examined users' evaluation of digital libraries based on their uses. The results show that users' evaluation of digital libraries is largely based on their own experience of using them. To be specific, digital library use affects its evaluation in two folds. First, the problems users encountered in their use

of digital libraries lead to their negative evaluation. Second, the availability of new features or design sets up a higher standard for digital library evaluation. The design of digital libraries has to take into consideration users' preference, experience, and knowledge structure. It seems impossible to design a one-size-fits-all digital library to satisfy all types of user needs. The findings of this study reveal some dilemmas, such as simplistic versus attractive interfaces, default versus customized interfaces, general help versus specific help, etc.

Interestingly, another study also reveals the same difference on digital library evaluation criteria between users and experts. Lai et al. (2014) investigate important criteria for digital library interface evaluation among students, teachers, and experts. For example, ease of use is ranked 1st for students, 5th for teachers, and 7th for experts respectively. Teachers care the most about presentation while experts consider design as the most important. Although the rankings are different, the findings show that seven criteria are deemed as important by all three groups: ease of use, searching, language, design, presentation, customization, and interaction. After reviewing relevant literature, Heradio et al. (2012) conclude that the standard definition of digital library usability, criteria, and measurements pose challenges for further research. Chapter 10 offers a more in-depth discussion of digital library evaluation criteria from different stakeholders' perspectives.

Usability research goes beyond just interface usability. Content usability, organizational usability, and interorganizational usability are also studied (Lamb, 1995). Among them, organizational usability is considered as one of the most important aspects for the development of digital libraries and associated interfaces. Elliott and Kling (1997) specify three levels of organization usability: individual, organizational, and environmental. All of these levels have an impact on interface design. Davies (1997) develops a model showing the roles played by different groups of stakeholders in the development of digital libraries. Following Davies' (1997) model, Xie and Wolfram (2002) illustrate three types of interactions among the players of a state digital library: influenced-based interactions, activities-based interactions, and communication-based interactions. These interactions in turn influence the enhancement of digital library interfaces.

Cultural issues, such as colors, symbols, metaphors, and language, also affect the usability of a digital library, indicating that the design of digital libraries needs to take into consideration cultural issues as well (Duncker et al., 2000; Liew, 2005, 2009). Even though the cultural aspect of usability has not been widely studied, some researchers have explored the area. Smith (2006) addresses the usability-culture connection by applying cognitive theory to the usability of digital libraries in a multiple culture, multiple intelligence context. In an empirical study, Arabic-speaking younger children show difficulty understanding all the representations of the ICDL (Bilal and Bachir, 2007a, b). Suggestions for how to consider cultural issues are discussed in Section "Usability Testing: Specific Digital Libraries and Specific Users."

HELP DESIGN

For the time being, digital libraries have no standard design. Users have to learn how to interact with each digital library. According to Nahl (1999), novice searchers are the main users of help features, and these users require different types of assistance, including help in learning about new IR systems. Novice users encounter many types of help-seeking situations in new searching environments. A help-seeking situation is characterized by a user engaged in information seeking within a digital library in order to achieve his/her tasks/goals and needing some form of help in the process (Xie and Cool, 2009). The situation of novice users working within a new search environment creates more challenges for

help seekers and for the design of effective help functionalities. However, users do not use help features because they are often not helpful to users. Monopoli et al. (2002) report only 34.6% of 246 respondents used the online help feature of a digital library, and 20% of those preferred human help.

Help features can be classified into explicit and implicit help features. Explicit help features refer to features that are labeled as "Help" or "?" while implicit help features refer to any features that facilitate users to solve their help-seeking situations even though they are not labeled as Help features. In their analysis of 120 information retrieval episodes, Xie and Joo (2010) also observe that searchers rarely use explicit help, especially help page views in their search processes. In their transaction log analysis of a digital library, Han et al. (2013a, b, 2014) confirm that users rarely visit help pages provided by the these system. Instead, searchers are more likely to use implicit help. Othman and Halim (2004) suggest that users prefer context-sensitive, implicit help features such as relevance feedback, term weighting, synonyms linked to terms in the thesaurus, and extensive search examples. Xie (2007) examines explicit and implicit help features in selected digital libraries. Explicit Help features are self-explanatory, with Help as part of the name. Implicit Help consists of a variety of features, such as FAQs, Contact Us, Advanced Search, About, Collection Descriptions, Site Map, Glossary, My Digital, How to View, etc. Some of the features can be under both explicit and implicit Help. For example, FAQs itself is an implicit Help feature. If FAQs is under the name of Help, then it is part of the explicit Help. For example, In American Memory Help, the explicit Help consists of implicit Help features, such as How to View, Search Help, FAQs, and Contact Us. These explicit and implicit Help features analyzed from the selected digital libraries can be classified into the following categories: general Help, search-related Help, collection-related Help, navigation Help, terminology Help, personalized and customized Help, and view-and-use-related Help. Six types of problems of help feature designs in digital libraries are identified: lack of standards, tradeoff between using explicit Help and implicit Help, tradeoff between using general Help versus specific Help, lack of interactive Help features, lack of dynamic presentation styles, and lack of Help features for advanced users and users who do not understand English.

Based on a series of user studies on the user interfaces of a digital library, Hill et al. (2000) notice that users prefer the following help features: (1) presenting search examples to assist users in formulating queries, (2) offering context-sensitive help, and (3) providing tutorials and FAQs. Frumkin (2004) suggests that a useful approach might be to make user interfaces complement to digital libraries. To conduct a usability evaluation of an automated help mechanism in a digital library, it is important to understand the searching behaviors of novice users and the help-seeking situations that arise while using it (Borgman and Rasmussen, 2005).

Xie and her associates have conducted a series of studies to identify help-seeking situations in information retrieval, evaluate help features, and inquire about users' perspectives to those help features. Xie and Cool (2006) discover that users acknowledge the importance of help mechanisms in using IR systems, but at the same time, express the ineffectiveness of existing help mechanisms and consequently tend to use those help features infrequently in their search process. Xie and Cool (2009) explore different help-seeking situations in using digital libraries. To be more specific, they identify fifteen unique help-seeking situations in searching digital libraries. Those situations are classified into seven categories of situations that users are unable to complete without a certain type or types of help: (1) inability to get started, (2) inability to identify relevant digital collections, (3) inability to browse for information, (4) inability to construct search statements, (5) inability to refine searches, (6) inability to monitor searches, and (7) inability to evaluate search results. Factors from users, tasks, digital libraries, and interaction

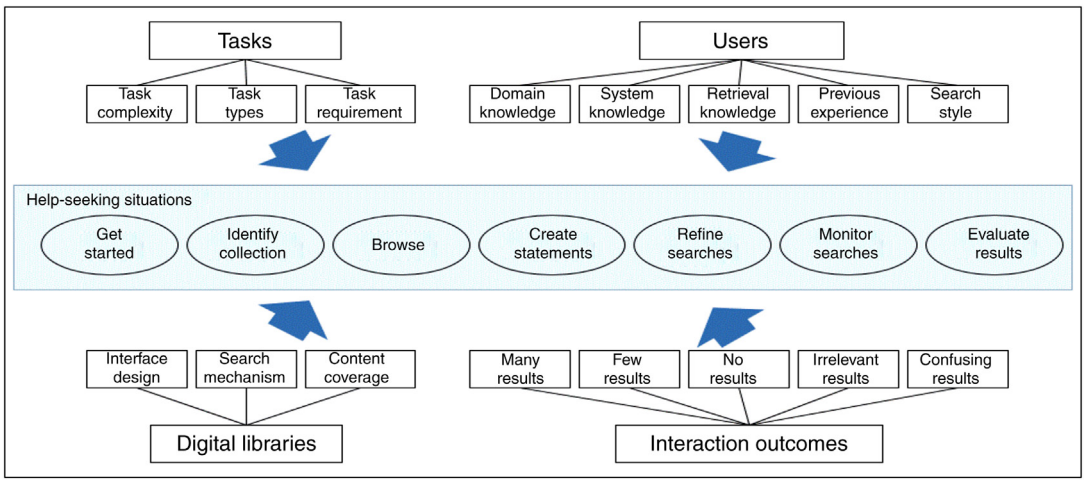

FIGURE 7.6 Factors Affecting Types of Help-Seeking Situations

Adapted from Xie and Cool, 2009, p. 490.

outcomes that affect help-seeking situations are also recognized. Fig. 7.6 presents the types of factors affecting help-seeking situations. Xie et al. (2013) comprehensively examine user engagement and different types of system support in interactive IR processes including applying help tactics. The challenge is to understand how users can convey their problems to the systems and how the systems can understand users' problems and offer appropriate help features to assist users to solve these problems. Compared to normal users, people with disabilities encounter unique help-seeking situations. The identification of help-seeking situations for blind users and the implications for digital library interface design is discussed in the next section.

To summarize, different types of explicit and implicit help features need to be offered in digital libraries. Here are some suggestions for the design of help mechanisms of digital libraries to solve different types of help-seeking situations:

- Overview of the digital library structure
- Intuitive interface design
- Context-sensitive knowledge assistance
- Interactive dialog protocol
- Search mechanism for identifying specific collection(s)
- Examples of how to create search statements
- Templates of searches based on task type and complexity
- Integrating the help page into actual browsing and searching page
- Demo of browsing options and structure
- Explicit and implicit feedback mechanisms
- Search history and search path options
- Different evaluation mechanisms for different types of tasks
- Examples for dealing with unsatisfied interaction outcomes
- FAQs

INTERFACE DESIGN FOR PEOPLE WITH DISABILITIES

Tim Berners-Lee, the founder of the World Wide Web, was quoted by the W3C saying, "The power of the Web is in its universality. Access by everyone regardless of disability is an essential aspect" (as cited in W3C, 1997, para. 1). Web Accessibility Initiative (http://www.w3.org/WAI/) widely develops guidelines that are regarded as the international standard for Web accessibility. Web Content Accessibility Guidelines (WCAG) 2.0 extends to all types of virtual communication including interactive multimedia content and is more usability oriented, including a navigable, meaningful sequence, and consistent navigation guidelines. It also covers several types of disabilities, such as cognitive, language, learning, and physical disabilities (Riberta et al., 2009). Snead et al. (2005) discuss functionality, usability, and accessibility in the digital library context. Accessibility is to assess how well systems allow users with disabilities to have equal use of information and services. The measures are associated with the World Wide Web Consortium or section 508 of the Rehabilitation Act.

Developers of digital libraries need to know that making them accessible for users with disabilities is a legal necessity as per the Americans with Disabilities Act (ADA). ADA mandates that all digital content available for public consumption be accessible to users with disabilities. For users with disabilities, this means the digital library interface and its constituent content and features should be accessible with screen-readers. Compliance with accessible Web design principles as those forwarded by the Web Content Accessibility Guidelines and Section 508 of the U.S. Rehabilitation Act are necessary. Blansett (2008) found that libraries were not yet fully in compliance at the time of the study. Southwell and Slater (2012) surveyed 69 US academic library Web sites and found that 58% of the sampled digital collection items were not screen-readable. After examining 64 academic and public libraries in Ontario, Oud (2012) identifies an average of 14.75 accessibility problems per library consisting of poor color contrast, lacking text alternatives for images, and tables that are not readable by screen readers. Yoon et al. (2013) suggest the integration of a high-level information architecture for users who use screen readers based on the analysis of accessibility barriers for visually impaired users.

People with disabilities require special assistance to access information items. The Digital Accessible Information System is a standard for Digital Talking Book. The standard makes it possible to organize the text within a structure and specify headings, subheadings, and pages numbers (Kerscher, 2002; Morgan, 2003). ALI is a project that creates a digital archive of DAISY books produced by the Swedish universities for students with reading disabilities consisting of journal articles, book chapters, and materials presented by teachers (Forsberg, 2007).

People with different types of disabilities have different requirements. The review of 20 Web design guidelines yielded the top recommendations for interface design for people with cognitive disabilities: use pictures, graphics, icons, and symbols with text; use clear and simple text; use consistent navigation and design on every page; and use headings, titles, and prompts (Friedman and Bryen, 2007). Borg et al. (2014) conclude that people with cognitive disabilities have different accessibility needs, requirements, and preferences, and these need to be further investigated and incorporated into the accessibility guidelines. Deo et al. (2004) describe the process of how to create a digital library for illiterate users:

- The first step is to conduct a user study to obtain user requirements via questionnaire and observing how subjects interact with a digital library interface. User requirements consist of ease of learning and ease of remembrance, no textual requirements, icons and visual display,

internationalization, localization, simple, easy to navigate, ease to use and tolerant of errors, useful content and robust design, providing contextual information, and supporting simple browsing strategy.

- The second step is to create paper prototype designs evaluated by subjects. Two interface design guidelines are preferred: an interface with a side menu of the collection to avoid the use of the navigation buttons and to go back to the Home page, and incorporation of audio support into the digital library interface.
- The third step is to test the usability of standard digital library interfaces and an interface designed for illiterate users. It is essential to reduce collection size and browsing structure complexity to minimize human memory overload.

In this section, blind users are used as an example to illustrate how to study their needs and design digital libraries to help users with disabilities. The global blind population exceeds 45 million (Pascolini and Mariotti, 2012), two million of which reside in the United States (American Foundation for the Blind, 2012). The blind comprise a significant user group that interacts with information retrieval systems, including digital libraries, in entirely different ways from sighted users. A "blind user" refers to an individual who lacks the functional sight to see information presented on a computer screen. For these users, interacting with an IR system is a listening activity. They predominantly rely on text-to-speech software called screen-reader (SR) to interact with computers and the Internet (Lazar et al., 2007). An SR identifies and interprets textual content on the screen and presents the screen information through a synthetic voice (Di Blas et al., 2004). In order to design digital libraries to be effectively used by blind users, developers and researchers need to understand the unique needs of blind users. The great promise of digital libraries becoming the gateway to the universal access to information cannot be realized if not all groups of users can use them effectively. Digital libraries represent one type of information retrieval system that as of yet is not commonly utilized by blind users.

Previous literature shows that the help needs of blind users have not been examined and considered. There are few studies directly investigating their help needs. Related research has identified multiple cognitive and physical constraints of the blind in information use on the Internet: (1) avoidance of pages containing severe accessibility problems, such as dynamic content (Bigham et al., 2007; Craven, 2003); (2) structural problems when browsing as well as difficulties with the serialized-monolithic presentation of SRs (Salampasis et al., 2005); (3) the sequential nature of interaction, meaning at any given point a blind user perceives only a snippet of the content and loses all contextual information (Lazar et al., 2007); (4) mere translation of text content with a synthetic speech and not a complete narration of information presented (Babu, 2011); important cues embedded in color, images and videos that aid in navigation and interpretation are lost (Leuthold et al., 2008); (5) cognitive overload from spending cognitive resources in trying to understand the browser, the Web site, and the SR simultaneously (Chandrashekar, 2010; Theofanos and Redish, 2003); and (6) improper labeling causing significant confusion, frustration, and disorientation, particularly for interface objects (Lazar et al., 2007).

Xie et al. (2015) performed a study with 15 blind users to explore types of help-seeking situations during their interactions with digital libraries. The blind participants were asked to conduct three search tasks, including known-item search, specific information search, and exploratory search, using American Memory Digital Collections. Findings of this study identify some unique help-seeking situations that blind users encountered at both the physical and cognitive levels. Nine main help-seeking situations at the physical level emerged from the data. They can be further classified into three subcategories:

(1) difficulty in accessing information, (2) difficulty in identifying current status and path, and (3) difficulty in efficiently evaluating information. Eight main help-seeking situations at the cognitive level were derived from the data. They can be further classified into four subcategories: (1) confusion about multiple programs and structures, (2) difficulty in understanding information, (3) difficulty in understanding and using digital library features, and (4) avoidance of a specific type of format or approach.

Corresponding design implications are suggested to overcome help-seeking situations at both physical and cognitive levels. For example, in order to help blind users understand the file name of an image, digital libraries should provide clear labels for alternative text, and most importantly, the alternative text has to be meaningful for blind users. In order to assist blind users to make sense of digital library structure, header information needs to offer an overview of a page, and it is essential for the screen reader to continuously inform blind users of the current section in a page. Moreover, standardization of home and resource page layouts in collections would greatly reduce user confusion and facilitate them to decipher the overall structure of the digital library or a page. See also Chapter 8 for a related discussion of information needs of people with disabilities and their use of digital libraries.

The research for supporting universal accessibility of digital libraries is still in its infancy. While most of the research has focused on the accessibility issues for people with disabilities, there is still a long way to go to make digital libraries universally accessible. Moreover, accessibility of digital libraries is only the basic requirement, since blind users first need to access digital libraries and their associated pages. Usability of digital libraries is the second requirement because ease of understanding and ease of using are vital for blind users to interact effectively with digital libraries. More importantly, the ultimate goal for IR is to assist users to achieve their tasks (Saracevic, 2007a, b, 2015). Utility, or the usefulness of digital libraries in helping users to accomplish their information needs and tasks, is the third requirement, and is the most difficult one to fulfill, as distinct disabilities lead to distinctly complicated physical and cognitive help-seeking situations. The main challenge is whether we can design one digital library to satisfy all users' needs, including users with and without disabilities.

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