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## Multilinguality in the Digital Library: A Review

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## Multilinguality in Digital Libraries: A Review

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Review

## Multilinguality in the Digital Library: A Review

### 1. Introduction

This article reviews literature on multilingual information access in digital libraries. As a natural consequence of increasing globalization and the advent and growth of the Internet, digital libraries have been created that not only cross borders, but also languages. The topic of the review covers the intersection of three research areas: cross-language information retrieval, multi-lingual information access, and digital libraries.

Cross-language information retrieval (CLIR) allows a user to query across languages (Peters and Sheridan, 2001, Oard and Diekema, 1998). Using CLIR in a collection containing documents with multiple languages, a source language query (e.g. in English) can retrieve relevant documents in one or more target languages (e.g., Dutch, Chinese, Arabic). The returned documents can then be translated into the source language for the English language reader. Multilingual information access (MLIA) is a broader term describing access (not limited to retrieval) to information across language boundaries and includes CLIR in addition to other areas such as multilingual summarization and cross-language question answering (Gey et al., 2006). A digital library (DL), sometimes referred to as electronic library or virtual library, is an organization that organizes and maintains an online collection of (born) digital or digitized materials and makes this collection available though the Internet (Lesk, 2005).

Multilingual digital libraries are digital libraries with content in more than one language, or that provide multilingual query access to a monolingual collection. The impetus behind the creation of multilingual digital libraries ranges from the practical to the grand and idealistic. Bringing together collections from various countries, regions, and cultures can provide quick and easy access to a wide range of information and ideas and can provide information access on a global scale (Yang et al., 2008, Maeda et al., 1998, Alessio, 2010), it also can preserve cultural heritage and advance agriculture (Jain and Gorla, 2006, Nichols et al., 2005). Multilingual digital libraries might also foster collaboration and lead to a deeper understanding between nations (Fox and Marchionini, 1998, Cousins, 2006).

Users of the multilingual digital libraries are quite diverse and range from children, economists, and cartographers, to European citizens (Bilal and Bachir, 2007a, Bilal and Bachir, 2007b, Geleijnse and Williams, 2007, Chias and Abad, 2009). Not surprisingly, the contents of these libraries reflect the diversity of their users. Among the multilingual content areas we found medical information, economics research, children's literature, Serbian culture, newspaper clippings, ancient Spanish maps, Indian theses, images, and legal literature (Lu et al., 2008, Zhou et al., 2006, Geleijnse and Williams, 2007, Hutchinson et al., 2005, Dudas, 2002, Calvanese et al., 2002, Tsang, 1997, Chias and Abad, 2009, Smits and Friis-Christensen, 2007, Clough and Sanderson, 2006, Urs et al., 2002, Francesconi and Peruginelli, 2004, Sheridan et al., 1997).

### 2. Scope

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5 This review brings together writings on multilingual information access, or multilinguality, in  
6 digital libraries. Criteria for inclusion in the review are journal articles and journal news  
7 briefs (with authors) reporting on multilingual aspects in digital libraries. Selected articles  
8 had to be written in English, Dutch or German or be available in English translation and  
9 indexed in one or more of the databases described below. Articles on digital libraries or on  
10 cross-language information retrieval individually are not part of the review.  
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12  
13 The literature included in this article resulted from searches in the following four  
14 electronic databases: ACM, ERIC, Library Literature, and Library, Information Science &  
15 Technology Abstracts. Search terms (keywords and subject or thesaurus terms) used were  
16 "digital libraries", "electronic libraries", "multilinguality", "multilingual", "multilingual  
17 materials", "cross-language information retrieval" and various Boolean combinations thereof.  
18 A few, additional articles were found in article bibliographies as well as serendipitously  
19 during the search process.  
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23 This is the first review on the topic of multilinguality in the digital library although reviews  
24 of related areas can be found. Oard and Diekema (1998) wrote an extensive review about  
25 research and practice in CLIR and, more recently, Kishida (2005) specifically focused on the  
26 technical issues that surface in CLIR. Bishop and Starr (1996) reviewed literature on social  
27 informatics of digital library use and infrastructure. Fox and Urs (2002) covered digital  
28 library research while Chowdhury (2006) examined articles on the usability of digital  
29 libraries and Bearman (2007) examined users and user needs. The most recent review we  
30 came across is on organizational and people issues in digital library research by Liew (2009).  
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### 33 **3. Organization**

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35 The review begins with examples of existing multilingual DLs and the collaborative efforts  
36 and projects behind the creation of these types of libraries. Next, we discuss the aspect  
37 that differentiates the multilingual DL from the regular DL: crossing the language barrier  
38 and the resulting problems and challenges therein. The review concludes with research  
39 investigations and solutions for the cross-lingual problems follow.  
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### 43 **4. Existing multilingual digital libraries**

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45 While many of the articles on multilingual DLs are made up of feasibility studies, prototype  
46 development efforts, announcements of future projects, or proposed frameworks (Lee et  
47 al., 2003, Braschler and Ferro, 2007, Amato et al., 2008, Chen and Ruiz, 2009, Jain and  
48 Goria, 2006, Downing and Klein, 2001) a number of multilingual DLs are fully operational and  
49 examples from the literature are presented below. In their analysis of 150 digital libraries  
50 in the US, Chen and Ruiz (2009) found only five that were multilingual: Meeting of  
51 Frontiers, France in America, Parallel Histories, The International Children's Digital Library  
52 (ICDL), and The Perseus Digital Library. Out of these five only the ICDL appeared in the  
53 literature surveyed for this review.  
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The International Children's Digital Library (ICDL) [1] contains a collection of children's literature in over 50 languages [2]. It was created with funding from the National Science Foundation (NSF) and the Institute for Museum and Library Services (IMLS) as a collaborative project between the University of Maryland and the Internet Archive. The intended audiences of the ICDL are children, their parents, and other adult researchers interested in children's literature (Hutchinson et al., 2005). Interestingly, the project includes children as design partners and uses the ICDL as a platform for research on multilingual access (Hutchinson et al., 2005),(Bilal and Bachir, 2007a).

The World Digital Library (WDL) [3] contains primary source cultural content in a wide number of formats from a growing number of national libraries and other institutions and is operated by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as well as the United States Library of Congress. The search interface is available in seven languages, ranked here in order of frequency of use: Spanish, English, Chinese, Portuguese, Russian, French and Arabic (Van Oudenaren, 2010). Sponsors of the library include Google and Microsoft. Van Oudenaren (2010) also reports over 10 million visitors since WDL's public launch. Most of these visitors hail from Argentina, Brazil, China, Columbia, France, Mexico, Portugal, Russia, Spain, and the United States.

Europeana [4]- the European Digital Library (TEL) - contains cultural and scientific materials and is funded by the European Union (Purday, 2009). The Europeans went through several stages of development that eventually resulted in Europeana. First, they created a website with information about national libraries of Europe as part of the Gabriel project (Gorman and Tran, 2002). Additional projects (TEL-ME-MOR) extended the national library collaboration to include national libraries from new European Union member countries and resulted in the integration of library resources and the ability to search across collections in the European Library (Cousins, 2006, Cousins et al., 2008, Braschler and Ferro, 2007, Fuegi and Segbert, 2006).

The digital library of the Caribbean (dLOC) [5] contains cultural, historical and research materials from the Caribbean (Wooldridge et al., 2009). DLOC is funded by a grant from the U.S. Department of Education and member contributions from dLOC partners.

Economists Online [6] contains references, open access full text publications and datasets by economists and is funded by the European Union through the Network of European Economists Online (NEEO) project (Geleijnse and Williams, 2007).

The Virtual Catalogue for Art History [7] contains bibliographic records from European art institutions. Formerly known as the Virtueller Katalog Kunstgeschichte (VKK) this meta catalog allows a search across the various catalogs. The project is funded by member fees (Hoyer, 2003).

Creating multilingual DLs requires collaboration on a large, often international, scale. Without exception the multilingual DLs described above are the result of collaborative projects. The next section describes some of the projects related to multilingual DLs that emerged from the literature.

## 5. Collaboration: Projects and Systems

While libraries have traditionally worked together in cooperative cataloging projects, museums with unique collections have often tended to work independently from each other (Kupietzky, 2007). In building a DL, collaboration is inevitable since it requires skills in various areas (e.g. computer science, library science, museum studies, arts, etc.) to build a digital library and additional skills such as linguistics, natural language processing, or cross-language information retrieval would be needed in cases of a multilingual DL. Funding from different agencies and foundations encourages collaboration in the form of projects with participants often hailing from several countries (Cousins et al., 2008, Gorman and Tran, 2002, Wooldridge et al., 2009) and between different organizations such as libraries and software companies (Calvanese et al., 2002). In some cases, these projects are collaboratively funded (Van Oudenaren, 2010). Other instances of collaboration manifest themselves in efforts to align national research agendas (Klavans and Schaüble, 1998) or with the inclusion of proposed collaborative models in research papers (Lee et al., 2003, Cousins et al., 2008).

The majority of the research on multilingual DLs originates in Europe since cooperation between nations forms the foundation of the European Union and cross-lingual information navigation is imperative to Europe's daily operations. The European CACAO Project (cross-language access to catalogues and online libraries) incorporated cross-language information retrieval techniques into an infrastructure that allows users of online catalogs and digital libraries to query libraries in one European language and retrieve textual materials originating in other European languages. This multilingual navigational infrastructure has been incorporated in later European digital library projects such as the European Library (Levergood et al., 2008, Alessio, 2010). The project also participated in the European Cross-language Evaluation Forum CLEF (see section 8)(Bosca and Dini, 2009).

Another European project is the DELOS Network of Excellence. DELOS conducts research in the area of digital libraries, developing relevant technologies for all aspects of the library. One example of a technology is the DelosDLMS, which is a modular digital library management system with multilingual support (Braschler and Ferro, 2007, Ioannidis et al., 2008). Also European is the LAURIN project which is building a digital library of digitized multilingual newspaper clippings. Newspaper articles can be searched through the use of a multilingual thesaurus (Calvanese et al., 2002, Calvanese et al., 2001). We could not find an instance of LAURIN online.

The MultiMatch Project is creating a search engine for multilingual multimedia cultural heritage objects (Amato et al., 2007, Amato et al., 2008) while the Rastko project works to provide access to a multilingual Serbian culture collection (Dudas, 2002).

The systems described in the literature are typically created for research purposes. We only include systems here that have a direct application or connection to online multilingual collection searching.

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3 MTIR is a Chinese-English information retrieval system that uses a bilingual dictionary for  
4 query translation in combination with a transliteration system to translated proper names.  
5 Multiple translation options are disambiguated using term co-occurrence information (Bian  
6 and Chen, 2000). Retrieved documents are translated using machine translation. Since the  
7 system is meant for use on the Web, the machine translations are carried out based on html  
8 tags. The system uses the HTTP protocol and can be easily integrated into web applications,  
9 potentially allowing for a bilingual online search. SPIRIT (Syntactic and Probabilistic  
10 Indexing and Retrieval of Information in Texts) originates from the 1980s as a monolingual,  
11 French and English system. It was expanded to be cross-lingual and uses reformulation rules  
12 that reformulate source queries into all possible target queries and use the document  
13 collection to disambiguate the translated queries (Fluhr et al., 1999). Eurovision is a cross-  
14 language image retrieval system that uses machine translation to translate queries into  
15 English which is then used to query the English-language index of the image captions (Clough  
16 and Sanderson, 2006). SIS-TMS is a thesaurus management system with a database scheme  
17 that allows storage and access to multiple multilingual thesauri and the connections between  
18 them (Doerr and Fundulaki, 1998). CLIR sometimes uses multilingual thesauri to get from  
19 the source language to the target language, which makes SIS-TMS especially relevant.  
20 Another terminological knowledge structure is used by SyDoM. SyDoM is a multilingual  
21 document system that uses a multilingual ontology to determine which terms to extract  
22 from documents for indexing (Roussey et al., 2007).  
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## 28 **6. Ways to cross the language barrier**

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31 The unique feature about multilingual DLs is that they allow information searching across  
32 two or more different languages. Achieving this feat requires crossing the language barrier  
33 to match the information need (query) to content (documents) in disparate languages.  
34 According to the CLIR literature, there are many options to cross from one language to  
35 another (Yang and Li, 2005). One can translate the query into the language of the document,  
36 one can translate the documents into the language of the query, one can translate both  
37 query and document into a so-called interlingual representation. Interestingly, another  
38 translation approach has emerged in the multilingual DL literature: translation of metadata  
39 (or surrogate) records (Van Oudenaren, 2010, Lee et al., 2003, Francesconi and Peruginelli,  
40 2004). Rather than translating an entire document it is much more efficient to translate  
41 the metadata record. This approach is especially suitable for collections with images and  
42 other non-textual materials that only have item level descriptions or metadata. A partial  
43 solution to crossing the language barrier is matching only on cognates (words that are  
44 shared between languages - typically proper names) in situations where the language scripts  
45 are the same (Buckley et al., 1998).  
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50 Translation knowledge comes from multilingual dictionaries, ontologies, and machine  
51 translation systems. This knowledge can be statistically extracted from text corpora. Most  
52 of these methods and translation knowledge sources are used in multilingual DLs.  
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55 Larson and cohorts (2002) harvest term translations from the library catalog of the  
56 University of California (over 10 million entries) to create a customized, multilingual  
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3 dictionary. Clinchant and Renders (2009) use a multi-language information retrieval model in  
4 combination with a multilingual dictionary that includes the source language.  
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7 Hodge (Hodge, 2000) provides an overview of knowledge organization systems (KOSs).  
8 Libraries have been organizing their collections using existing KOSs such as the Library of  
9 Congress Classification system or Library of Congress Subject Headings (LCSH) or their  
10 own homespun varieties. Unlike keywords, which are derived from bibliographic records or  
11 document full-text, subject terms are assigned to collection items by human catalogers or  
12 subject experts and provide high quality access points. Building on these knowledge systems  
13 in multilingual DLs requires a multilingual KOS such as a multilingual thesaurus. Schiel et al.  
14 use a computer supported indexing method to create a multilingual thesaurus (Schiel and  
15 Sousa, 2003, Schiel et al., 1999). Yang et al. (2008) create a multilingual thesaurus fully  
16 automatically by applying algorithms to a parallel aligned Chinese-English corpus. Calvanese  
17 et al. (2002) express the relationships between concepts in their multilingual thesaurus in a  
18 logical formalism used in query processing. The framework for the integration of  
19 multilingual heterogeneous thesauri is described by Nikolai et al. (1998). These thesauri can  
20 be used for indexing and browsed for retrieval. In the medical domain, Lu et al. (2008)  
21 developed a Chinese translation of the MeSH (Medical Subject Headings) in order to  
22 provide access to medical websites for Chinese language users. Smits and Friis-Christensen  
23 (2007) investigated whether it is desirable to use one common ontology which combines  
24 various structures together and concluded that creating such a structure is unrealistic.  
25 Sheridan et al. automatically created a similarity thesaurus drawn from a parallel corpus in  
26 the legal domain (Sheridan et al., 1997). While this structure is not a thesaurus in the strict  
27 sense of the word, the small groups of highly correlated multilingual terms function well to  
28 expand a monolingual query with multilingual terms.  
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34 Mixed translation methodologies are followed by Monroy et al. (2010) who use a multilingual  
35 glossary and an ontology, Brisaboa et al. (2002) use three dictionaries and ontologies to  
36 provide federated search capabilities across multiple digital libraries in different languages.  
37 Wang et al. (2006) mine the web to extend their translation dictionary.  
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## 40 **7. Other problems and challenges**

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42 Crossing the language barrier is not the only challenge facing the multilingual DL. Additional  
43 problems and/or challenges are related to: data management and representation of  
44 information (Klavans and Schauble, 1998); interoperability (linking between systems) (Fox  
45 and Marchionini, 1998); development (Hutchinson et al., 2005); and copyright (which was not  
46 directly addressed in any of the retrieved articles).  
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### 49 *Language barrier*

50 Cross-language information retrieval, which takes place in multilingual digital libraries,  
51 requires translation or crossing the language barrier. Errors introduced during the  
52 translation negatively impact search results in multilingual digital libraries. Even in a  
53 monolingual retrieval situation, lexical ambiguity and synonymy cause retrieval problems.  
54 With every additional language added to the mix, difficulties increase. Three factors cause  
55 translation errors: lack of translations for technical terms, acronyms, and proper names;  
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3 the erroneous breaking up of non-compositional phrases in translation, and; the addition of  
4 multiple translation senses of a word to the translation. In contrast to the CLIR literature,  
5 the multilingual digital library literature does not contain many articles about the  
6 translation problem. Problems with crossing the language barrier are most commonly  
7 associated with translation resources. Chung et al. and Wang et al. present a solution to the  
8 problem of missing dictionary terms in a query translation (Chung et al., 2004, Wang et al.,  
9 2006). Queries tend to be only a few words long and, when one or more words cannot be  
10 translated because they do not appear in the dictionary, retrieval is going to fail. The  
11 researchers mine the Web by extracting translations from bilingual search results and by  
12 adding these translations to the multilingual dictionary. Bian and Chen attempted to solve  
13 the missing dictionary terms by applying a transliteration algorithm to convert proper  
14 names, which make up a large percentage of untranslatable terms, from one writing system  
15 (Chinese) into another (English)(Bian and Chen, 2000).  
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### 20 *Data management*

21 Repository management and storage of content and metadata is a challenge to all digital  
22 libraries and has certain aspects that complicate matters for multilingual DLs. Instructions  
23 and metadata forms and vocabularies need to be translated into various languages and still  
24 make sense to users (Bia et al., 2005, Karvounarakis and Kapidakis, 2000). Digital library  
25 interfaces also need to be translated into the languages supported by the library, a process  
26 known as internationalization or localization. Multilingual document indexing is also  
27 challenging because each language has different characteristics and rules to decide  
28 between content bearing terms that you want to index and stop words that you want to  
29 remove (Roussey et al., 2007). Additional problems are created when using optical character  
30 recognition (OCR) on documents, especially for non-Latin character sets (Govindaraju et al.,  
31 2004).  
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### 36 *Representation*

37 Displaying text on a computer screen requires characters (letters or pictograms) to be  
38 represented as codes in the computer. This process is called character encoding and is  
39 required for readability, text processing such as indexing, and making text searchable.  
40 There is a confusing number of encoding schemes available but the most widely used  
41 encoding on the Internet is the UTF-8 Unicode encoding (Graham, 2000). According to the  
42 Unicode Consortium [8] Unicode can represent any character in any written language.  
43 Unfortunately not all existing languages are currently included. New languages are  
44 continually being added however. In 1998, Maeda et al. developed a technology to enable  
45 viewing of multilingual documents in a web browser (Maeda et al., 1998). Nowadays, these  
46 capabilities are included in most common browsers. That said, options might be limited for  
47 languages that are less common. Digital library software, such as Greenstone, support non-  
48 Latin character sets. This open-source software was used in a Mongolian newspaper project  
49 (Matusiak and Munkhmandakh, 2009). Since not all encoding schemes play nicely together  
50 and not all languages are represented in any of them, multilingual digital libraries may face a  
51 difficult challenge in finding a suitable encoding scheme.  
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### 56 *Development*

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3 Most multilingual DL projects require (cross-cultural) collaboration (see section 5) and face  
4 the challenge of running projects successfully with large cross-cultural teams. Case studies  
5 are particularly well suited to learn more about the challenges involved in the development  
6 of multilingual DLs. Hutchinson et al. (2005) mention that the cultural aspects involved with  
7 building international software are perhaps the most complex issue to deal with. Cultural  
8 differences between different nationalities are often subtle and not easily understood by  
9 outsiders. They resolved this issue by creating a multicultural team to work on their library  
10 and advocate testing the interface with target audiences from all languages and cultures  
11 involved. A related problem these researchers reported is that of deciding what content  
12 was suitable (safe) for their underage users. Geleijnse and Williams (2007) reported  
13 another content development problem with the realization that they needed to get  
14 economists on board to contribute content to the DL. Liew (2005) warns us that creating a  
15 DL with indigenous cultural resources content requires careful representation as these  
16 resources can easily be misinterpreted. DL policies based on cultural norms of the cultural  
17 group are necessary. In her case study of the Asian Film Connection DL Afifi (2000) lists  
18 financial problems for DL development . It proved difficult to secure funding and resources  
19 for an educational DL project.  
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### 26 *Interoperability*

27 Brisaboa et al. describe an architecture for combining digital libraries into one by creating a  
28 federated search interface (Brisaboa et al., 2002). The challenge here is to translate a  
29 single user query into the languages of all participating libraries, fire them off to each  
30 library and, finally, combine all the result sets into a single result list. Collaboration is  
31 intricately linked to interoperability. Operating in a multilingual, multicultural, and  
32 sometimes even multigenerational arena, is a challenge for the International Children's  
33 Library (Hutchinson et al., 2005). Similarly, the European Library project not only required  
34 interoperability on a technical level but also on socio-political and semantic levels (Cousins et  
35 al., 2008). Semantic interoperability sometimes occurs when combining different libraries  
36 with their different thesauri into one resulting in the intellectual and technical challenges  
37 of merging various knowledge structures (Kramer et al., 1997, McCulloch et al., 2005, Yang  
38 et al., 2008, Levergood et al., 2008).  
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## 43 **8. Research on multilingual digital libraries**

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45 Several articles mention or describe research agendas and research directions for  
46 multilingual information access (Klavans and Schauble, 1998, Gey et al., 2005, Gey et al.,  
47 2006). Common themes from these papers are: the introduction of real users or use cases in  
48 evaluation; extend the research to include more languages and media types; leverage  
49 experiences of real-world-deployments. Gey et al. (2005) add the goal of a multilingual web  
50 with search engines that search across languages and unified model for cross-language  
51 retrieval which combines the translation and retrieval components into a single algorithm.  
52 There is a significant body of research in CLIR but the uptake of this research into robust  
53 working systems with real users has thus far been limited (Gey et al., 2009, Peters, 2007).  
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3 System researchers typically build experimental systems to investigate certain approaches.  
4 They run experiments with their systems and compare results to decide whether certain  
5 approaches or algorithms are feasible and would lead to desired improvements. Much of the  
6 research in cross-language information retrieval takes place in various evaluation campaigns,  
7 in which participating systems are applied to various retrieval tasks. Systems are ranked in  
8 their abilities to complete these tasks successfully (Peters, 2007). While the TREC  
9 evaluation campaign included a cross-language evaluation track as early as 1997, the first  
10 evaluation campaign solely devoted to cross-language information retrieval is the NTCIR  
11 Workshop which started in 1999 (Kando et al., 1999) shortly followed by the Cross-Language  
12 Evaluation Forum (CLEF) which started in 2000 (Peters and Braschler, 2001).

13 This long history of evaluation has resulted in a large collection of scientific data that can  
14 be used for further study. Agosti et al. propose to create a digital library to collect all of  
15 this data (Agosti et al., 2007). CLEF uses European languages and has developed tasks that  
16 are increasingly more realistic and relevant to the real world (Peters and Braschler, 2001,  
17 Peters, 2007). This is important since these evaluation campaign tasks challenge  
18 researchers and stimulate research in the task specific areas. Also, development teams of  
19 multilingual DLs are much more likely to participate in pragmatic evaluations because they  
20 require fewer system modifications and the results can be more easily applied. Examples of  
21 system-based research are described in the following section. The articles assembled here,  
22 with a few exceptions, have been selected based on their connection to multilingual digital  
23 libraries (a connection made either in the title or text of the article).

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30 Query translation is a common approach to cross the language barrier and is highly  
31 applicable to multilingual DLs. Wang et al. describe a query translation system which can be  
32 connected to any digital library with monolingual (Chinese or English) content (Wang et al.,  
33 2004, Wang et al., 2006). This system mines the web for translations that do not occur in  
34 the dictionary (new terms, proper names). Although the researchers report "promising"  
35 results, it does not appear the system is ready for the real world just yet. Another query  
36 translation study was carried out by Bosca and Dini (2009) who participated in the CLEF  
37 evaluation forum with their system using various ways to expand the query with additional  
38 terms. The system performed well compared to other evaluation participants. In their CLEF  
39 experiments Clinchant and Renders (2009) used multi-language query translation trying to  
40 capitalize on multilingual documents (documents containing more than one language) but the  
41 results did not show improvement in retrieval results. Braschler and Ferro (2007) carried  
42 out a feasibility study to pick between two translation approaches (query or record) and to  
43 determine if the two alternatives might be combined. Kanazawa and his fellow researchers  
44 (2001) experimented with query translation techniques, and Yang et al. (2008) researched  
45 two different algorithms for automatic thesaurus construction benchmarking them against  
46 an earlier technique. Azzopardi et al. (2007) experimented with a model to generate  
47 simulated known-item queries for experimental systems that were comparable to real human  
48 queries which is useful for testing systems and modeling user query behavior.

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53 Another way to do cross-language research is to prototype the system which you want to  
54 eventually build so that you can test whether the approach works on a smaller scale. A  
55 prototype, experimental system was applied to integrate various ontologies by Smits and  
56 Friis-Christensen (2007) who concluded that this approach was not viable. Larson et al.  
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3 (2002) used a prototype system to create a multilingual, conceptual mapping resource based  
4 on data mined from a large library catalog (described earlier in this paper). Bamman et al.  
5 (2010) tested a method for transferring structural information such as XML tags and  
6 chapter and section information) from source documents to target (translated) documents  
7 and achieved high accuracy. Ferber (1997) tested a system that automatically assigns  
8 subject terms based on the title of the document. This system used a set of documents  
9 with manually assigned subject headings to determine what descriptors to assign to the new  
10 documents. Results were found to be variable.  
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14 The majority of multilingual DL research appears to be system based. However, we did come  
15 across a few user-centered studies as well. Bilal and Bachir carried out two research  
16 studies with child users of the International Children's Digital Library (Bilal and Bachir,  
17 2007a, Bilal and Bachir, 2007b). In the first study, the researchers tested interface design  
18 while the second study they observed the child subjects conducting searches and they also  
19 held group interviews to study the subjects' information seeking behavior. A qualitative  
20 study of the bilingual thesaurus-based interface called Searchling was carried out by  
21 Stafford et al. (2008). Fifteen users were asked to carry out three structured tasks to  
22 test the system as to test whether it aided in query formulation. Cousins (2006) studied the  
23 effect of a portal on usability. Clough and Sanderson (2006) ran user experiments with  
24 their Eurovision cross-language image retrieval system based on two search tasks.  
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28 Another type of multilingual DL research is the case study. Researchers studied the  
29 development of a multilingual library (Afifi, 2000, Liew, 2005) or a multilingual knowledge  
30 management system (O'Leary, 2008).  
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### 33 9. Conclusion

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35 The articles reviewed in this paper show that there are a limited number of existing  
36 multilingual digital libraries but that their number is growing. Creating a multilingual digital  
37 library is typically a collaborative effort between different organizations and people with  
38 different areas of expertise. Enabling users to search across languages requires translation  
39 resources to cross the language barrier, which can be challenging depending on the language  
40 and resource availability. Additional challenges were found to be in the data management,  
41 representation (dealing with different fonts and character codes), development (creating  
42 international software, cross-cultural collaboration), and interoperability (system  
43 architecture and data sharing). Research in multilingual digital libraries was mostly system  
44 based involving experimental systems or system prototypes. A small number of user studies  
45 involved testing user interfaces and the study of information seeking behavior. Based on the  
46 literature however, it is mostly unclear who is using existing multilingual DLs, nor do we have  
47 much information about the extent of this use. There might be no uptake of research in  
48 systems with actual users but there is no research on the users in actual systems either.  
49 We can conclude that existing multilingual DLs are understudied and remain a bit of an  
50 enigma. Evaluation campaigns need to emphasize realistic evaluations that include working  
51 systems and actual users or use case scenarios. This might be the only way to ensure that  
52 CLIR research will find its way into existing multilingual DLs and that the library users find  
53 their way into the research literature.  
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## Websites

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