# An Identification of the Image Retrieval Domain from the Perspective of Library and Information Science with Author Co-citation and Author Bibliographic Coupling Analyses

JungWon Yoon (윤정원)*
EunKyung Chung (정은경)**
Jihye Byun (변지혜)***

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## ABSTRACT

As the improvement of digital technologies increases the use of images from various fields, the domain of image retrieval has evolved and become a growing topic of research in the Library and Information Science field. The purpose of this study is to identify the knowledge structure of the image retrieval domain by using the author co-citation analysis and author bibliographic coupling as analytical tools in order to understand the domain's past and present. The data set for this study is 245 articles with 8,031 cited articles in the field of image retrieval from 1998 to 2013, from the Web of Science citation database. According to the results of author co-citation analysis for the past of the image retrieval domain, our findings demonstrate that the intellectual structure of image retrieval in the LIS field consists of predominantly user-oriented approaches, but also includes some areas influenced by the CBIR area. More specifically, the user-oriented approach contains six specific areas which include image needs, information seeking, image needs and search behavior, image indexing and access, indexing of image collection, and web image search. On the other hand, for CBIR approaches, it contains feature-based image indexing, shape-based indexing, and IR & CBIR. The recent trends of image retrieval based on the results from author bibliographic coupling analysis show that the domain is expanding to emerging areas of medical images, multimedia, ontology- and tag-based indexing which thus reflects a new paradigm of information environment.

Keywords: Image Retrieval, Domain Analysis, Knowledge Structure, Author Co-citation Analysis, Author Bibliographic Coupling

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* Associate Professor, School of Information, University of South Florida, Tampa, FL, USA (jyoon@usf.edu) (First Author)
** Associate Professor, Department of Library and Information Science, Ewha Womans University, Seoul, Korea(echung@ewha.ac.kr) (Corresponding Author)
*** Researcher, Center for Teaching and Learning, Ewha Womans University, Seoul, Korea (jhbyun@ewha.ac.kr)
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# 1. Introduction

Visual information had been a primary communication venue for more than 20,000 years, but during the last 500 years, phonetic alphabets dominated images as a form of communication (Jörgensen 2003, ix). Compared to text information, there are difficulties in creating, disseminating, and accessing visual information. However, with the development of digital technologies, the production and use of images have become pervasive in recent decades. Images are not only used for specific purposes, such as medical diagnoses, fingerprint/face identification, and biological analysis, but also for general purposes. For example, journalists, educators, designers, and students use images to convey messages more effectively while they conduct work-related tasks. In addition to work-related tasks, the development of digital cameras and social network environments have enabled people to create, share, and use images for personal entertainments.

As images become burgeoning sources of communication, image retrieval is one of the more crucial topics in the field of information retrieval. Researchers have attempted to enhance image retrieval via various approaches. For instance, researchers, mostly from the computer science field, have focused on how to utilize visual features for indexing and retrieving images; and these efforts are applied to specific types of image collections such as medical images, trademarks, fingerprint/face recognitions, and so on. Researchers in the library and information science (LIS) field and museum communities have attempted to represent images through verbal representations; additionally, the metadata schemes and controlled vocabularies have been developed to represent visual information. The research has also been conducted for exploring users' image seeking behaviors, image uses in their lives, and image-related-behaviors in the context of social media.

Research on image retrieval has been conducted actively for several decades, and with the changes of digital environments and users' information behaviors, topics related to image retrieval have evolved tremendously. Therefore, it is meaningful to see a knowledge structure of the image retrieval domain, in order to understand how the domain has developed, what the current research topics are, and what should be pursued as future research agendas. There has been a line of research attempts to overview existing researches in the image retrieval fields, and the focus of this line has addressed the gap between Content-Based Image Retrieval (CBIR) and description-based image retrieval while emphasizing the significance of bridging the gap between these two research communities (Rasmussen 1997; Goodrum 2000; Chu 2001; Enser 2008b). Another line of research focused on reviewing the research endeavors conducted by CBIR communities

(Eakins 1996; Idris and Panchanathan 1997; Marsicoi, Cinque and Levialdi 1997; Rui, Huang and Chang 1999; Smeulders et al. 2000; Veltkamp and Tanase 2002; Kherfi and Ziou 2004; Lew et al. 2006; Liu et al. 2007; Datta et al. 2008). This line of research predominantly overviewed CBIR techniques and image retrieval systems by utilizing CBIR techniques. Compared to the research efforts already conducted in the CBIR community, there is lack of studies which focus on description-based image retrieval that is frequently conducted in the LIS field. The number of researchers and the number of publications within the LIS community is relatively small when compared to those in the CBIR community. However, this does not mean that the approaches by the LIS field are less important than CBIR approaches. The LIS community provides unique viewpoints which are not often considered by the CBIR community, but nonetheless makes contributions to understand features of image attributes, image users' behaviors, and the representation of visual information.

Therefore, this research attempts to focus on understanding image retrieval studies from a LIS perspective. More importantly, this study will further adopt two analysis techniques in order to demonstrate the past and present of the image retrieval domain: author co-citation analysis and author bibliographic coupling analysis. Since the author co-citation analysis was introduced by White and Griffith (1981), it has been substantially utilized for visualizing intellectual structures, but it only shows a view on the past structure of knowledge due to citation time lags. This current study, in addition to using author co-citation analysis, utilizes author bibliographic coupling analysis to show the current structure of the image retrieval domain (Lee 2008; Zhao and Strotmann 2008). Together with these two complementary analytical techniques, this current research aims to demonstrate the knowledge structure of the image retrieval domain from the past to the present. One of immediate implications of this current research is to provide an overview of the image retrieval field and to provide insightful guidelines toward the future paradigm of image retrieval.

## 2. Overview of image retrieval

Image retrieval is, like other document formats, basically a process of finding images which are related to users' information needs, if not being oversimplified. Therefore, with the ultimate purpose of enhancing image retrieval effectiveness, the research on image retrieval has investigated components of image retrieval process. These components include the understanding characteristics of images, image users' needs and their seeking behaviors, indexing (representing) images, and

matching image representations with image needs representations (queries), and CBIR implications in the LIS field.

## 2.1 Characteristics of Image

Multi-layered meanings of an image are unique features. Therefore, the understandings on image characteristics and attributes provide a rationale of what should be accomplished in the indexing of images (Jaimes and Chang 1999; Layne 1994). Research on image attributes is concerned with identifying, categorizing, and characterizing image attributes. Shatford (1986), Layne (1994), Jamies and Chang (2000), Burford, Briggs and Eakins (2003), and Hollink, Schreiber, Wielinga, and Worring (2004) provided conceptual frameworks for indexing multi-layered meanings of images. Each of these researchers adopted various taxonomies for presenting various image attributes, but as summarized by Westman (2009), the image attributes could be placed into three categories, each with their own subcategories: Non-visual (Bibliographical, Physical and Contextual), Syntactic (Global, Local, and Compositional), and Semantic (Generic, Specific and Abstract).

Whereas the above studies theoretically explored image attributes for providing a way to index images, there are studies which empirically analyze image attributes. This line of studies attempted to reveal which image attributes are important to users while searching for images and suggest which image attributes should receive more attention when indexing images. The most commonly used method of research is to analyze users' image search queries or search requests (narrative descriptions of image needs). Some studies established experimental settings and provided the participants with tasks of searching for images (Chen 2001; Choi and Rasmussen 2003; Hastings 1995; Jörgensen 1995; Ornager 1997), while others analyzed real queries or requests (Armitage and Enser 1997; Chung and Yoon 2009; Enser and McGregor 1992; Goodrum and Spink 2001; Keiser 1994; Yoon and Chung 2011). Image collections and user groups in these studies vary significantly, such as special collections and user groups such as journalists and art historians (Chun 2001; Choi and Rasmussen 2003; Hastings 1995; Ornager 1997), collections in picture libraries or museums (Armitage and Enser 1997; Enser and McGregor 1992), and general Web environment including queries from a search engine (Chung and Yoon 2009; Goodrum and Spink 2001) and narrative description of queries from a social Q&A site (Yoon and Chung 2011). It is natural to examine the users' queries and questions because they demonstrate which image attributes are used when users express their image needs. In addition to the query/question analysis, researchers attempted to understand image attributes when examining how people describe and

sort images. A describing task is adopted on the basis of the assumption that attributes, which are described while viewing an image, reveal perceived or pertinent attributes of the image (Jörgensen 1995). Image descriptions were obtained through users' descriptions on images within an experimental setting (Greisdorf and O'Connor 2002; Jörgensen 1995; Laine-Hernandez and Westman 2006; O'Connor, O'Connor and Abbas 1999) or through tags from a social networking site, such as Flickr (Rorissa 2008; Yoon 2009). It has been considered that image attributes which are not extracted from a describing task can be revealed through a sorting task, as sorting is based on the notion of similarity where the individual, cultural and contextual backgrounds are embedded. Therefore, whereas the describing task closely mirrors known-item searches, a sorting task mirrors browsing (Jörgensen 1995). Börner (2000), Jörgensen (1995), Rorissa and Hastings (2004), and Rogowitz, Frese, Smith, Bouman, and Kalin (1998) attempted to understand image perceptions through sorting tasks.

## 2.2 Users' Behaviors

Understanding users' search behaviors is a crucial way to improve user-oriented image retrieval systems, because users represent their image needs through search queries and by interacting with image retrieval systems when searching for images needed. Searching strategies have been analyzed from several aspects: searching methods adopted by users (textual queries, content-based queries, and browsing), searching method transitions throughout the search process, complexity of queries and search sessions, query modification patterns, criteria for relevance assessments, and so on. To understand search strategies, various collections and user groups were employed, including search logs from web search engines, special collections for professional users like journalists, users in advertising industries, art historians, users of general digital image collections and so on. This line of research also demonstrates that there are several factors that influence search strategies: users' expertise, the domain that users participated in, task types leading to the image search, image need types, types of search topic, the time available, the expected amount of images to be found, and so on (Choi 2010; Choi and Rasmussen 2002; Frost et al. 2000; Fukumoto 2006; Markkula and Sormunen 2000; Matusiak 2006; Westman and Oittinen 2006; Westman, Lustila and Ottinen 2008). While these studies attempted to understand image search behaviors by integrating users and contextual aspects, there are studies which analyze features of image search patterns by focusing on the length of search queries, the length of search sessions, query modification patterns, features of failed queries, and frequency distribution of image search

terms. These studies usually conducted transaction log analyses from web search engines (Chung and Yoon 2010; Goodrum, Bejune and Siochi 2003; Goodrum and Spink 2001; Jörgensen and Jörgensen 2005; Pu 2005; 2008).

An image may convey different meanings to users (or viewers), depending on the context in which the users are situated. Generally, search queries cannot fully represent contextual backgrounds, and thus a line of research evolved which explores the context of general image users' image behaviors by analyzing descriptions of user needs including data from social Q&A websites (Chung and Yoon 2011; Cunningham and Masoodian 2006; Cunningham, Bainbridge and Masoodian 2004; Yoon and Chung 2011). These studies attempted to understand users' image needs through intended use of images, goals, related tasks, and any other image needs which are not directly related to the content of images but their image needs. There are several studies which conducted contextual examinations on image seeking in workplaces. Conniss, Ashford, and Graham (2000) analyzed the work-related image search behaviors from various domain-professional users, and suggested classes of image use, classes of image search, and contextual framework which provide a holistic view of the image seeking environment. Pisciotta, Dooris, Frost, and Halm (2005) examined the use of images at the university with the purpose of informing the design of digital image systems. McCay-Peet and Toms (2009) also attempted to understand journalists and art historians' image uses within the context of a work task model.

## 2.3 Indexing

Since the content of images is not linguistic, the image indexing faces unique challenges. A primary challenge of image retrieval has been referred to as "semantic gap," which originated from the CBIR research field (Smeulders et al. 2000). The term usually refers to the gap between an image's low-level features and the higher level of semantic meanings, it not only includes object recognitions but also abstract meanings with contexts, emotions, and connotative meanings (Jörgensen 2007).

Stvilia, Jörgensen, and Wu (2012) explained that the non-linguistic features of image content make "image indexing more dependent on both human indexers and the use of image-knowledge organization and representation systems (KOS) to provide content models that are understandable and searchable by humans." (p.99). Image indexing which is conducted by human indexers is mostly done by a description-based approach, and within the professional practitioner environment, a description-based approach has been predominantly adopted for providing access to image

collections. Two major metadata standards for image collections are Visual Resources Association (VRA) Core Categories Version 3.0 and Categories for the Description of Works of Art (CDWA). Dublin Core and Anglo-American Cataloging Rules, 2nd ed. (AACR2) are also often adopted for cataloging image collections, although these are not specialized for image collections. In addition to the metadata schemes, several standards for indexing languages have been developed: Art and Architecture Thesaurus (AAT), Union List of Artist Names (ULAN), Thesaurus of Geographic Names (TGN), Library of Congress Thesaurus for Graphic Materials (TGM), and Iconographic Classification Scheme (ICONCLASS). Although these metadata schemes and standards for vocabulary control have been developed for enhancing accessibility to visual resources through textual representations, another gap between professional indexers and users has been recognized (Jörgensen 2007). With the advent of Web 2.0, research and projects utilizing social tagging for image indexing are underway (Bar-Ilan et al. 2012; Stvilia, Jörgensen and Wu 2012; Yoon 2009). The common research questions are: how users assign index terms for future uses, the differences between index terms given by users and professionals, how to develop a user-centered thesaurus by using social tagging, and so on. The overall consensus on this line of studies is that user-generated tags are useful resources which may enhance image retrieval effectiveness, but cannot replace traditional indexing schemes generated by the professionals. Therefore, a combination of user-generated tags and index terms provided by professionals is desirable.

## 2.4 CBIR implications

Although the text-based approach has been a practical indexing mechanism for visual materials, the limitation of verbal representation for visual materials has caught researchers' attention. Specifically, computer scientists have actively developed CBIR techniques which retrieve visual materials by using visual features, such as color, texture, shape, and so on (Jörgensen 1999). CBIR approaches can be explained by using three processing tiers. The aim of the first tier is to represent digital images in the form of low-level visual features, such as color, texture, and shape. These low-level features are extracted through a statistical process and are presented as the set of feature vectors. At the second tier, based on the information provided by shape, texture, and color processing, the objects and scenes in the image are recognized. Object recognition requires several techniques: segmentation which separates an image into regions of similar attributes, feature analysis which analyzes various features of the segmented image, and grouping these features for the purpose of recognizing objects. The third tier attempts to capture high-level semantics are influenced by

socio-cultural contexts, although most current CBIR techniques do not discuss the third level of image attributes (Enser 2008a; Jörgensen 2003).

The CBIR techniques depend on perceptual similarity, but it is only one of the elements that is utilized during the process of image similarity judgment (Jörgensen 2003). Rather, as Smeulders et al. (2000) addressed, people tend to rely on semantic similarity. The distinctions between information extracted by CBIR techniques from visual features of an image and the semantics which people observe from the image is called 'semantic gap,' (Smeulders et al. 2000). The CBIR communities have attempted to resolve this gap by involving the concept of verbal representations. Techniques for automatic annotation and ontology-based semantic image retrievals are the main efforts of semantic image retrieval. However, despite the huge amounts of research in the CBIR community, the current semantic image retrieval focuses on recognizing denotative attributes, and thus high-level semantics involving connotative features are rarely addressed (Enser, Sandom and Lewis 2005).

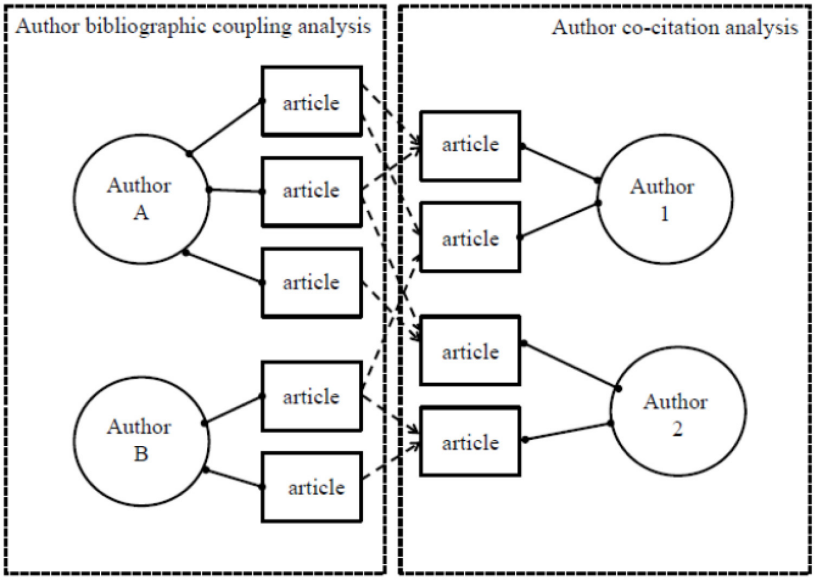
# 3. Research Method

## 3.1 Data collection

In order to identify the knowledge structure of image retrieval from the perspective of the library and information science field, a data set was collected. To gather a set of data for this study, the Web of Science was used as a data source and the search was performed on April 18, 2013. When searching for the topic of "image retrieval" with options of all coverage, all types of paper, and SCI-expanded, SSCI, A&HCI, initially 11,146 items were retrieved. Among 11,146 items, when the scope was narrowed down with "information science and library science" as a subject, 254 items were extracted. From the 254 items, 8,031 references were found with an approximate average of 32 references per paper. Since there are different variations of the same author name, the authority control for author names were conducted. For instance, an author called "Peter Enser", could be used in various formats such as "Enser, P.", "Enser P.G.B.", and "Enser, PGB" in the reference lists. In order to control various versions of author names, the last name and first initial were used for consistency.

### 3.2 Data analysis

The intellectual structure of image retrieval in the LIS field is manifested in 254 publications with 8,031 references by using the author and cited-author as unit of analysis. The analyses contain two folded: author co-citation analysis (ACA) and author bibliographic coupling analysis (ABCA) which were utilized to identify the domain effectively is shown in Figure 1. One approach for understanding the domain is to utilize author co-citation which identifies the field structure by co-cited authors, as introduced by White and Griffith (1981). Although the analysis method of author-based co-citation has been utilized by a substantial amount of research, the limitation of this method was that it could not reflect the current state of knowledge due to the citation time lags. In order to demonstrate the current knowledge structure of fields, the author bibliographic coupling analysis was introduced by Zhao and Strotmann (2008) and Lee (2008) and has been utilized recently. When adopting these two approaches, this current study demonstrates the present and the past of the image retrieval domain. In order to visualize the results of two analyses, author co-citation and bibliographic coupling, three techniques were adopted: the multidimensional scaling, hierarchical clustering, and pathfinder network with parallel nearest neighbor clustering (PNNC) (Lee 2006).

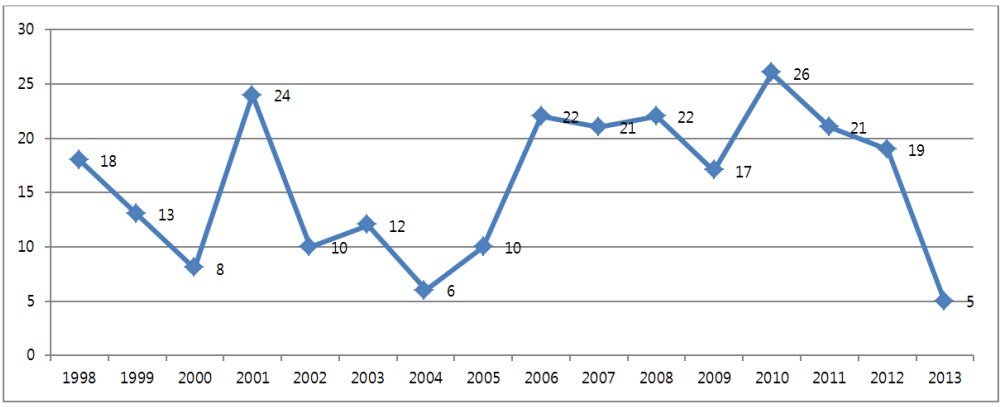



〈Figure 1〉 Comparisons between author co-citation and author bibliographic coupling analyses (Lee, J.Y. (2008). p. 178. reprinted.)

# 4. Results

## 4.1 Overview

The distribution of publications per year is shown in Figure 2. Among a total of 254 articles on image retrieval in the field of library and information science, the first publication on image retrieval appeared in 1998. As Smeulders, Worring, Santini, Gupta, and Jain (2000) mentioned, the number of research articles on image retrieval including CBIR increased since 1997. There were a large number of articles in 2001, which marked the emerging and spreading period of internet and web technologies. Although publications have fluctuated each year, there are more publications produced in recent years as compared with the early years of image retrieval. It is noted that since the searching period is in April 18, 2013, the number of publications in 2013 is relatively low.

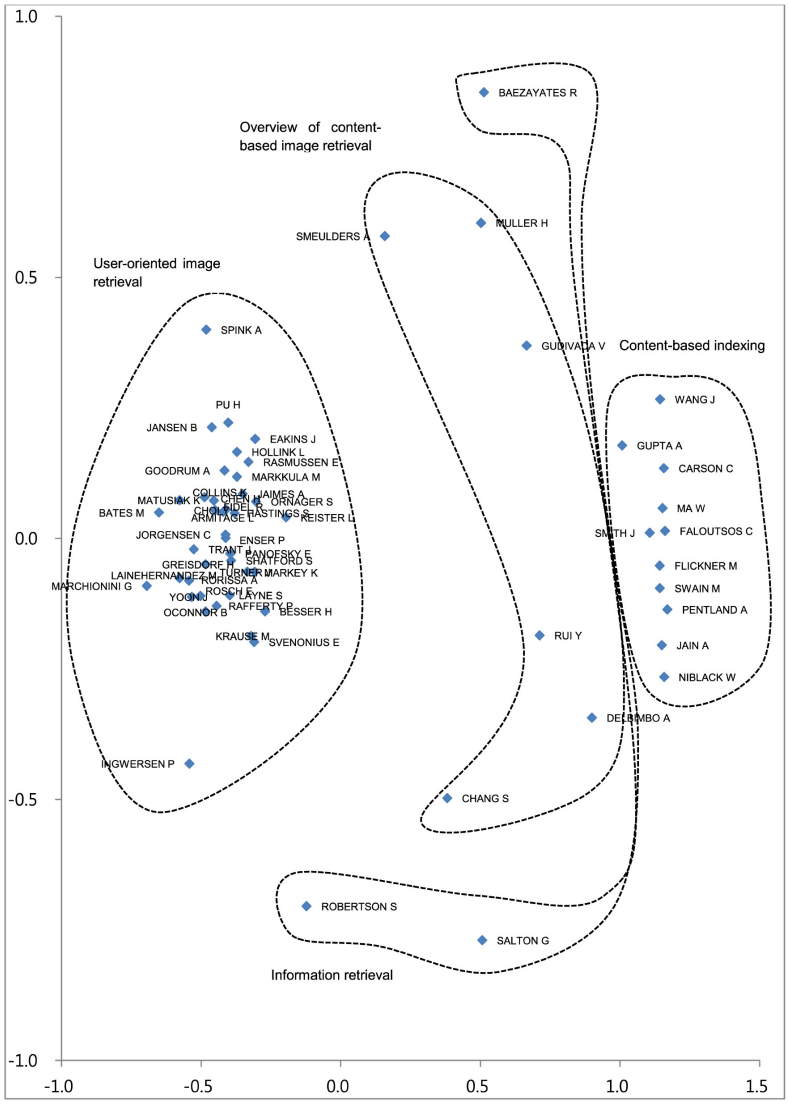



〈Figure 2〉 Distribution of article publications per year

In terms of publishing image retrieval articles through the venue of journals, three journals: *Journal of the American Society for Information Science and Technology* (previously *Journal of the American Society for Information Science*), *Information Processing and Management*, and *Journal of the American Medical Informatics Association*, were found to be the primary sources of discussion for image retrieval according to the distribution of journal publications presented in Appendix A. The three journals published more than 50% of the total articles from 1998 to 2013.

## 4.2 Image retrieval domain in the past: author co-citation analysis

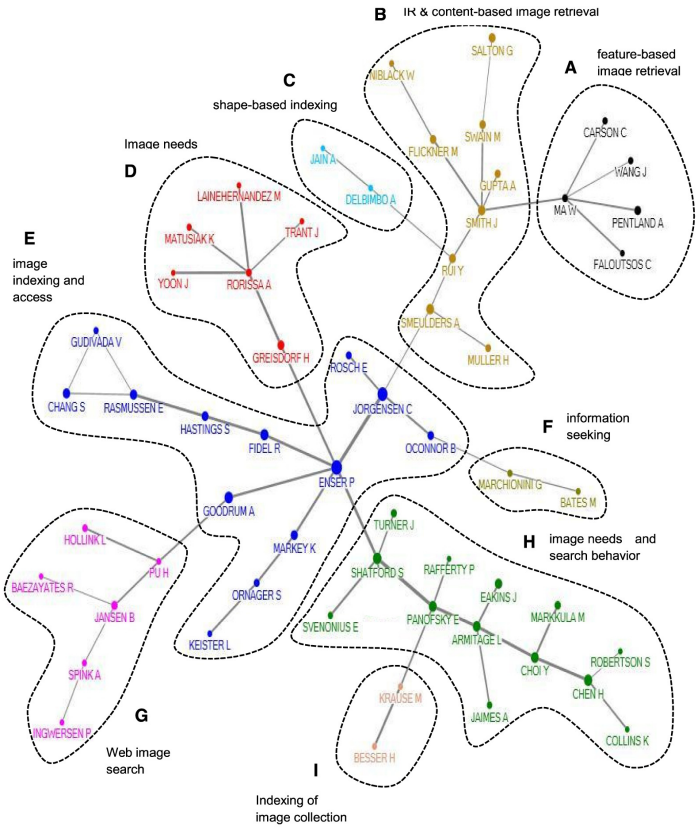
From 58 cited authors with more than 12 citations in Appendix B, the results of the three analyses were presented through the multidimensional scaling, hierarchical clustering analysis (Ward method), and pathfinder network with parallel nearest neighbor clustering (PNNC). First, the map of the multidimensional scaling was shown by using hierarchical clustering analysis in Figure 3.




〈Figure 3〉 The map of multidimensional scaling with hierarchical clustering by author co-citation analysis

Four clusters are recognized: user-oriented image retrieval, overview of content-based image retrieval, information retrieval, and content-based indexing. Among these four groups of clusters, two distinctive groups with some distance on the map could be demonstrated. First, a substantial size of single cluster deals with user-oriented image retrieval including concept-based indexing, users' image needs, and image searching/seeking behaviors. The other group focuses primarily on content-based approaches which consist of three clusters: overview of content-based image retrieval, information retrieval, and content-based indexing. As the three clusters in terms of content-based image retrieval are close to each other, the area of IR (information retrieval) is connected to both overviews of content-based image retrieval and content-based indexing.

In order to demonstrate more specific areas of image retrieval, the results of pathfinder network with parallel nearest neighbor clustering (PNNC) were shown in Figure 4. The network was clustered into nine groups from group A to group I.



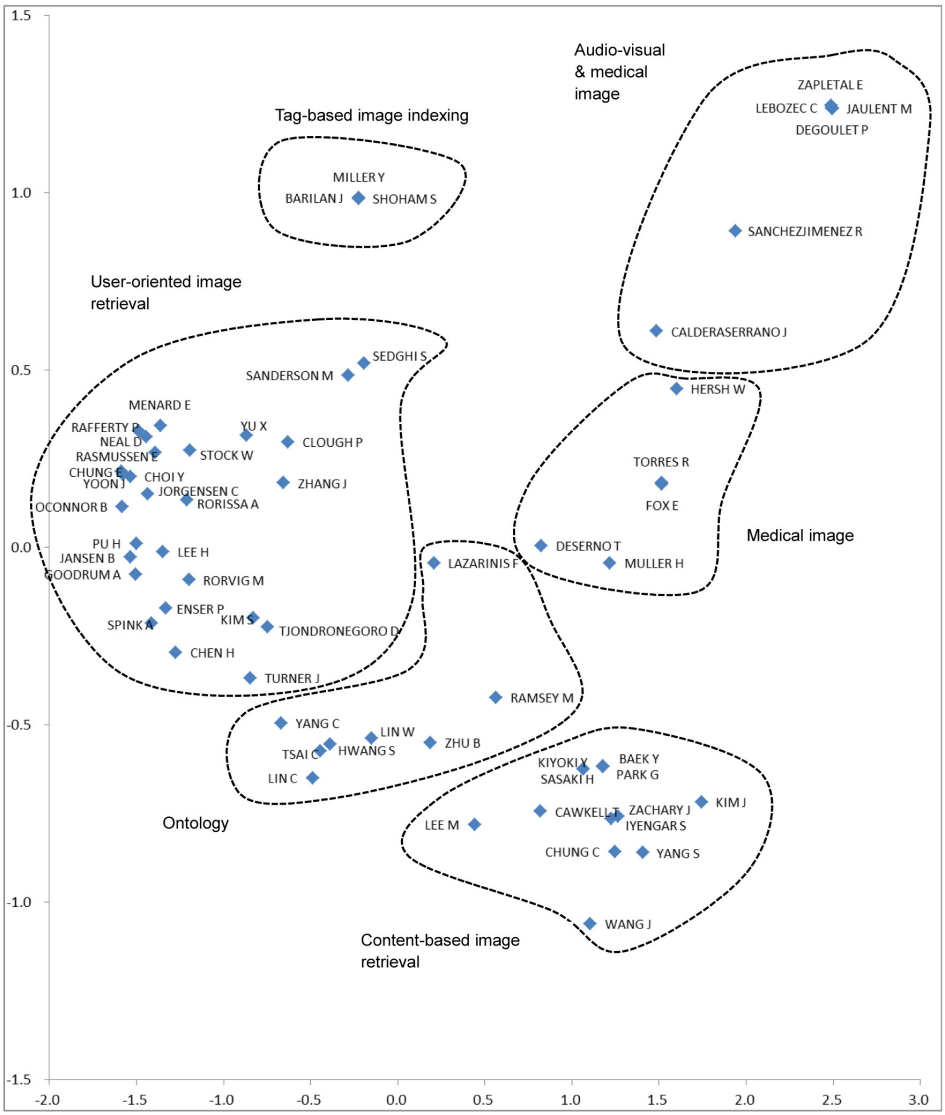

〈Figure 4〉 The pathfinder network with PNNC clustering by author co-citation analysis

Among the nine clusters, two groups of clusters can be divided into two areas such as content-based image retrieval and concept-based image retrieval. First, while the content-based image retrieval contains clusters A, B, and C, the concept-based image retrieval includes cluster D, E, F, G, H, and I. For content-based image retrieval, three areas were being identified: IR & content-based image retrieval, shape-based indexing, and feature-based image retrieval. Among three areas, the area of IR & content-based image retrieval is demonstrated to be substantial and centric, connecting the other two areas. As identified on the map of multidimensional scaling, the area of information retrieval (IR), which is not an image specific area, is found to be close to the content-based image retrieval. In addition, more specific areas such as shape-based image indexing and feature-based image retrieval are demonstrated in the pathfinder network and clustering results. On the other hand, for the concept-based image retrieval, six sub-areas are identified two major areas including image indexing and access and image needs and search behavior. The areas of image indexing and access and image needs and search behavior are found to be relatively considerable sizes for research trends. In specific, the area of image indexing and access is connected to four other areas such as image needs, web image search, information seeking, and image needs and search behavior but not to the area on indexing of image collection. While the area of image indexing and access plays a centric role in this network, the other major area, image needs and search behaviors, is connected to only two other associated areas, the indexing of image collection, and image indexing and access. Similarly, the area of information retrieval (IR) affects the areas of content-based image retrieval. The area of information seeking is found to be related to the areas of concept-based image retrieval, in particular, the area of image indexing and access.

### 4.3 Image retrieval domain in the present: author bibliographic coupling analysis

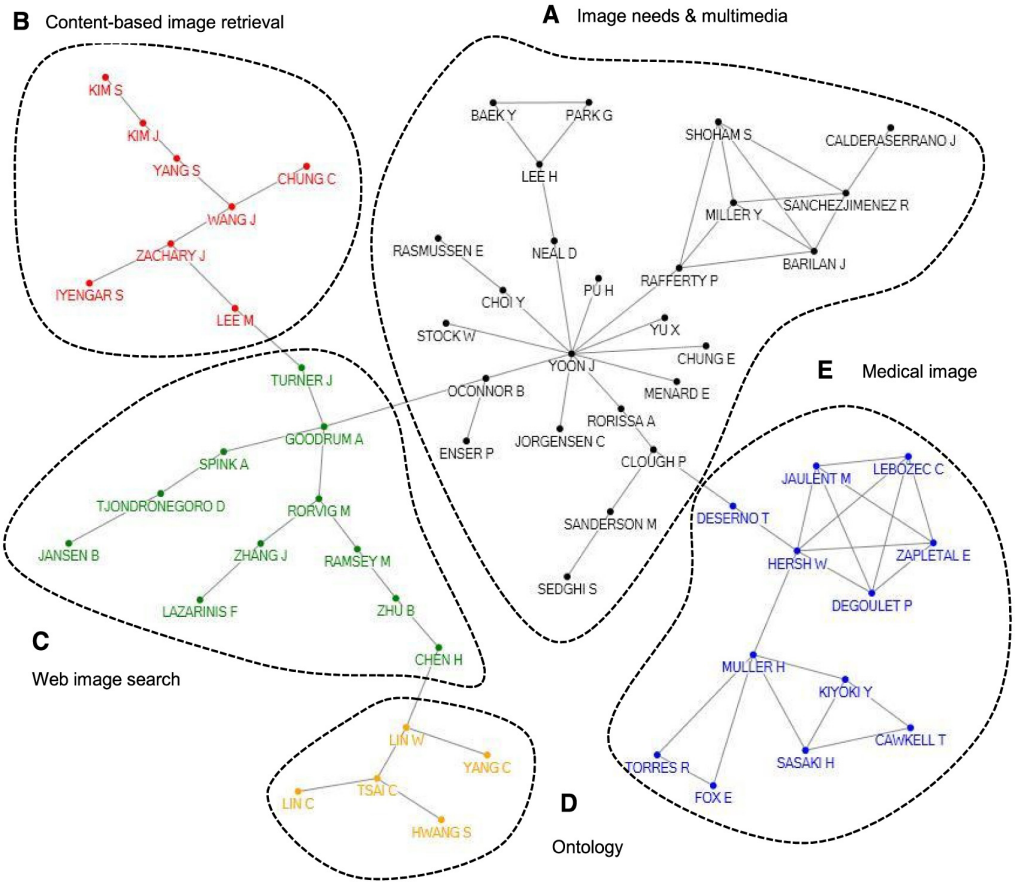
In order to view the field of image retrieval with more current trends, 61 authors with more than two authorship were visualized in terms of the author bibliographic coupling analysis (refer to Appendix C). As shown in Figure 5, the map from the multidimensional scaling with hierarchical clustering (Ward method) demonstrated six clusters including audio-visual & medical image, tag-based image indexing, medical image, ontology, content-based image retrieval, and user-oriented image retrieval areas. Compared with the results of author co-citation analysis, which shows recent past trends of the image retrieval field, more specialized areas which reflect the current related trends were being revealed. Newly emerging areas in the analysis of author bibliographic coupling

are identified in the four clusters including audio-visual, medical image, tag-based image indexing, and ontology. On the other hand, the area of concept-based image retrieval in the author co-citation analysis is specified in terms of user-oriented image retrieval with a substantial amount of research endeavors. In addition, the tag-based image indexing, which is collective indexing for images from end-users, is closer to the area of user-oriented image retrieval. The areas of ontology and content-based image retrieval are found to be close to each other.




〈Figure 5〉 The map of multidimensional scaling by author bibliographic coupling

When the pathfinder network and parallel nearest neighbor clustering (PNNC) were applied as shown in Figure 6, five clusters are then identified. Compared to the map of multidimensional scaling, similar areas such as content-based image retrieval, medical image, image needs, multimedia, and ontology are demonstrated. More importantly, the area of web-based image search is notable in this network. As the area of image needs and multimedia is found to be a considerable research field, such area is connected to content-based image retrieval, web-based image search, and medical image. The area of ontology is connected to the area of web-based image search.




〈Figure 6〉 The pathfinder network with PNNC clustering by author bibliographic coupling analysis

## 5. Discussion

With the development of digital technology, images have been substantially utilized as one significant information resource and media. To meet the trends of image use, the field of image retrieval has been researched along with various perspectives. This current study attempted to visualize the intellectual structure of the image retrieval field with two analytical tools. The results are compared with four areas of image retrieval such as characteristics of image, users' behaviors, indexing, and CBIR implications, as shown in Table 1. Since more detailed areas were depicted, the pathfinder network with PNNC clustering and the multidimensional scaling map with PNNC clustering were selected from the author co-citation analysis for the past status and from author bibliographic coupling analysis for the current trends, respectively.

Since the features of image are meaningful and significant for indexing images and identifying users' needs for image, the area on the image characteristics has been studied for identifying users' image needs within users' expressions. Probably the most dominant type of research is to identify the characteristics or attributes of image in terms of users' queries, requests, and questions. Hence, the characteristics of image embedded in the users' image needs are recognized as one area of image retrieval field. Recently, the area on the characteristics of image is expanding to more diverse types of information resources, such as the multimedia. In addition to image, the audio-visual information resources which include some types of medical images have been studied to in a way of identifying the users' needs. On the other hand, research endeavors to understand the users' image behaviors have been conducted. In the past, three approaches have played significant roles for analyzing users' image behaviors. First, traditional information seeking theories and concepts were utilized to understand users' behaviors for image. Then, users' image behaviors have been discussed in two directions such as general behaviors and web-oriented behaviors. However, more current research on image behaviors demonstrated focused image behavior research in the context of web due to the widespread of internet and web technologies while conducting general user-centered image retrieval studies.

From the studies on image indexing, there have been two primary approaches in the past such as general discussions on image indexing and access and indexing issues on specific image collections. While the discussions on image indexing specialized in specific collections were abundant in the past, recently, we can identify research agendas including ontology-based image indexing and collective tag-based image indexing. Clearly, a transition of research topics is found from overall indexing issues and indexing of specific image collections to ontology-based and tag-based

image indexing as research and projects which utilizes social tagging for image indexing are underway (Bar-Ilan et al. 2012; Stvilia, Jörgensen and Wu 2012; Yoon 2009) with the advent of the Web 2.0 environment. For CBIR-related topics, there were feature-based image retrieval, shape-based indexing, and IR & CBIR topics in the past. But recently, we identified that there is a topic area for CBIR. In addition, the research trends showed that there is an emerging area of medical image in the field of image retrieval.

〈Table 1〉 Comparison of image retrieval areas

| Area | Past[1)] | Present[2)] |
|---|---|---|
| Characteristics of image | Image needs | Audio-visual & medical image |
| Image behaviors | Information seeking<br>Image needs and search behavior<br>Web image search | User-oriented image retrieval<br>(Web image search) |
| Indexing | Image indexing and access<br>Indexing of image collection | Ontology<br>Tag-based image indexing |
| CBIR | Feature-based image retrieval<br>IR & CBIR<br>Shape-based indexing | CBIR |
| Other | | Medical image |

## 6. Conclusion

We demonstrated the past and current status of image retrieval domain with a LIS perspective based on two analytical tools: author co-citation analysis and author bibliographic coupling analysis. For the purpose of this study, a data set with 245 articles with 8,031 cited articles in the field of image retrieval from 1998 to 2013 was analyzed and visualized in terms of the multidimensional scaling map and pathfinder networks with PNNC clustering.

The identification and visualization of image retrieval field from a LIS perspective show at least four aspects of valuable insights and topic transitions of image retrieval field. First, there is a clear call for interdisciplinary approaches. Compared to the past of image retrieval research, more diverse information resource types are involved in the research of image retrieval such as audio-visual information types. Moreover, a specific subject field, namely, medical area, is

1) <Figure 3> The Pathfinder network with PNNC clustering by author co-citation analysis
2) <Figure 4> The map of multidimensional scaling by author bibliographic coupling analysis

recognized to be interrelated to the audio-visual resource type. This combination of resource type and field might require more collaboration from various disciplines of areas for image retrieval research. Second, in terms of users' image behaviors, the context of image searching environments should be considered. More research is identified to be on the context of web-based image searching behaviors which reflect the fact that more and more users search images on the web, rather than through specialized or in-house collection of images. In the near future, mobile environments for image searching may be considered as one prime context of image retrieval. Third, when considering image indexing, clearly topic transitions are demonstrated from image indexing to ontology- and tag-based image indexing. This transition shows that image retrieval research reflects the newer paradigm of image retrieval, which includes the semantic web and collective indexing for information retrieval. Lastly, the results of this study identify emerging areas of image retrieval such as the medical image retrieval.

## References

[1] Armitage, L. H. and Enser, P. G. 1997. "Analysis of User Need in Image Archives." *Journal of Information Science*, 23(4): 287-299.

[2] Bassecoulard, E., Lelu, A. and Zitt, M. 2007. "Mapping Nanosciences by Citation Flows: A Preliminary Analysis." *Scientometrics*, 70: 859-880.

[3] Börner, K. 2000. "Extracting and Visualizing Semantic Structures in Retrieval Results for Browsing." In *Proceedings of the 5th ACM Conference on Digital Libraries,* 234-235.

[4] Burford, B., Briggs, P. and Eakins, J. P. 2003. "A Taxonomy of the Image: on the Classification of Content for Image Retrieval." *Visual Communication*, 2(2): 123-161.

[5] Choi, Y. and Rasmussen, E. M. 2002. "Users' Relevance Criteria in Image Retrieval in American History." *Information Processing & Management,* 38(5): 695-726.

[6] Choi, Y. and Rasmussen, E. M. 2003. "Searching for Images: The Analysis of Users' Queries for Image Retrieval in American History." *Journal of the American Society for Information Science and Technology*, 54(6): 498-511.

[7] Choi, Y. 2010. "Effects of Contextual Factors on Image Searching on the Web." *Journal of the American Society for Information Science and Technology,* 61(10): 2011-2028.

[8] Chu, H. 2001. "Research in Image Indexing and Retrieval as Reflected in the Literature." *Journal of the American Society for Information Science and Technology*, 52(12): 1011-1018.

[9] Chung, E. K. and Yoon, J. 2009. "Categorical and Specificity Differences between User-Supplied Tags and Search Query Terms for Images. An Analysis of Flickr Tags and Web Image Search Queries." *Information Research*, 14(3): 1-22.

[10] Chung, E. and Yoon, J. 2010. "An Exploratory Analysis on Unsuccessful Image Searches." In *Proceedings of the American Society for Information Science and Technology*, *47*(1): 1-2.

[11] Chung, E. and Yoon, J. 2011. "Image Needs in the Context of Image Use: An Exploratory Study." *Journal of Information Science*, *37*(2): 163-177.

[12] Conniss, L. R., Ashford, A. J. and Graham, M. E. 2000. *Information Seeking Behaviour in Image Retrieval: VISOR I Final Report.* Newcastle-upon-Tyne: University of Northumbria.

[13] Cunningham, S. J. and Masoodian, M. 2006. "Looking for a Picture: An Analysis of Everyday Image Information Searching." In *Proceedings of the 6th ACM/IEEE-CS Joint Conference,* 198-199.

[14] Cunningham, S. J., Bainbridge, D. and Masoodian, M. 2004. "How People Describe Their Image Information Needs: A Grounded Theory Analysis of Visual Arts Queries." In *Proceedings of the 2004 Joint ACM/IEEE Conference,* 47-48.

[15] Datta, R. et al. 2008. "Image Retrieval: Ideas, Influences, and Trends of the New Age." *ACM Computing Surveys*, 40(2): 1-60.

[16] Eakins, J. P. 1996. "Automatic Image Content Retrieval: Are We Getting Anywhere?" *ELVIRA-PROCEEDINGS,* 121-134.

[17] Enser, P. G. B. and McGregor, C. G. 1992. *Analysis of Visual Information Retrieval Queries.* London: British Library.

[18] Enser, P. G. B., Sandom, C. J. and Lewis, P. H. 2005. "Automatic Annotation of Images from the Practitioner Perspective." *Image and Video Retrieval,* 3568: 497-506.

[19] Enser, P. G. B. 2008a. "Visual Image Retrieval." *Annual Review of Information Science and Technology*, 42(1): 1-42.

[20] Enser, P. G. B. 2008b. "The Evolution of Visual Information Retrieval." *Journal of Information Science*, 34(4): 531-546.

[21] Frost, C. O. et al. 2000. "Browse and Search Patterns in a Digital Image Database." *Information retrieval*, 1(4): 287-313.

[22] Fukumoto, T. 2006. "An Analysis of Image Retrieval Behavior for Metadata Type Image Database." *Information processing & management*, 42(3): 723-728.

[23] Glanzel, W. and Czerwon, H. J. 1996. “A New Methodological Approach to Bibliographic Coupling and Its Application to the National, Regional, and Institutional Level.” *Scientometrics,* 37: 195-221.

[24] Goodrum, A. and Spink, A. 2001. “Image Searching on the Excite Web Search Engine.” *Information Processing & Management*, 37(2): 295-311.

[25] Goodrum, A. A. 2000. “Image Information Retrieval: An Overview of Current Research.” *Informing Science*, 3(2): 63-66.

[26] Goodrum, A. A., Bejune, M. M. and Siochi, A. C. 2003. “A State Transition Analysis of Image Search Patterns on the Web.” *Image and Video Retrieval*, 2728: 281-290.

[27] Greisdorf, H. and O’Connor, B. 2002. “Modelling What Users See When They Look at Images: A Cognitive Viewpoint.” *Journal of Documentation*, 58(1): 6-29.

[28] Hastings, S. K. 1995. “Query Categories in a Study of Intellectual Access to Digitized Art Images.” In *Proceedings of the ASIS Annual Meeting*, 32: 3-8.

[29] Hollink, L. et al. 2004. “Classification of User Image Descriptions.” *International Journal of Human-Computer Studies*, 61(5): 601-626.

[30] Idris, F. and Panchanathan, S. 1997. “Review of Image and Video Indexing Techniques.” *Journal of Visual Communication and Image Representation*, 8(2): 146-166.

[31] Jaimes, A. and Chang, S. F. 1999. “Conceptual Framework for Indexing Visual Information at Multiple Levels.” *IS&T/SPIE Internet Imaging*, 3964: 2-15.

[32] Jörgensen, C. and Jörgensen, P. 2005. “Image Querying by Image Professionals.” *Journal of the American Society for Information Science and Technology*, 56(12): 1346-1359.

[33] Jorgensen, C. 1995. “Classifying Images: Criteria for Grouping as Revealed in a Sorting Task.” *Advances in Classification Research Online*, 6(1): 65-78.

[34] Jörgensen, C. 1999. “Access to Pictorial Material: A Review of Current Research and Future Prospects.” *Computers and the Humanities*, 33(4): 293-318.

[35] Jörgensen, C. 2003. *Image Retrieval: Theory and Research.* Lanham, USA: Scarecrow Press.

[36] Jörgensen, C. 2007. “Image Access, the Semantic Gap, and Social Tagging as a Paradigm Shift.” *Advances in Classification Research Online*, 18(1).

[37] Kherfi, M. L. and Ziou, D. 2004. “Image Retrieval Based on Feature Weighting and Relevance Feedback.” *2004 International Conference on Image Processing,* 689-692.

[38] Kuusi, O. and Meyer, M. 2007. “Anticipating Technological Breakthroughs: Using Bibliographic Coupling to Explore the Nanotubes Paradigm.” *Scientometrics*, 70: 759-777.

[39] Laine-Hernandez, M. and Westman, S. 2006. "Image Semantics in the Description and Categorization of Journalistic Photographs." In *Proceedings of the American Society for Information Science and Technology*, 43(1): 1-25.

[40] Layne, S. S. 1994. "Some Issues in the Indexing of Images." *Journal of the American Society for Information Science*, 45(8): 583-588.

[41] Lee, J. Y. 2006. "A Novel Clustering Method for Examining and Analyzing the Intellectual Structure of a Scholarly Field." *Journal of the Korean Society for Information Management*, 23(4): 215-231.

[42] Lee, J. Y. 2008. "Bibliographic Author Coupling Analysis: A New Methodological Approach for Identifying Research Trends." *Journal of the Korean Society for Information Management*, 25(1): 173-190.

[43] Lew, M. S. et al. 2006. "Content-Based Multimedia Information Retrieval: State of the Art and Challenges." *ACM Transactions on Multimedia Computing, Communications and Applications*, 2(1): 1-19.

[44] Liu, Y. et al. 2007. "A Survey of Content-Based Image Retrieval with High-Level Semantics." *Pattern Recognition*, 40(1): 262-282.

[45] Markkula, M. and Sormunen, E. 2000. "End-User Searching Challenges Indexing Practices in the Digital Newspaper Photo Archive." *Information Retrieval*, 1(4): 259-285.

[46] De Marsicoi, M., Cinque, L. and Levialdi, S. 1997. "Indexing Pictorial Documents by Their Content: A Survey of Current Techniques." *Image and Vision Computing*, 15(2): 119-141.

[47] Matusiak, K. K. 2006. "Towards User-Centered Indexing in Digital Image Collections." *OCLC Systems & Services*, 22(4): 283-298.

[48] McCay-Peet, L. and Toms, E. 2009. "Image Use within the Work Task Model: Images as Information and Illustration." *Journal of the American Society for Information Science and Technology*, 60(12): 2416-2429.

[49] O'Connor, B. C., O'Connor, M. K. and Abbas, J. M. 1999. "User Reactions as Access Mechanism: An Exploration Based on Captions for Images." *Journal of the American Society for Information Science*, 50(8): 681-697.

[50] Ornager, S. 1997. "Image Retrieval: Theoretical Analysis and Empirical User Studies on Accessing Information in Images." In *Proceedings of the ASIS Annual Meeting*, 34: 202-211.

[51] Pisciotta, H. A. et al. 2005. "Penn State's Visual Image User Study." *Libraries and the Academy*, *5*(1): 33-58.

[52] Pu, H. T. 2005. “A Comparative Analysis of Web Image and Textual Queries.” *Online Information Review*, 29(5): 457-467.

[53] Pu, H. T. 2008. “An Analysis of Failed Queries for Web Image Retrieval.” *Journal of Information Science*, 34(3): 275-289.

[54] Rasmussen, E. M. 1997. “Indexing Images.” *Annual Review of Information Science and Technology*, 32: 169-196.

[55] Rogowitz, B. E. et al. 1998. “Perceptual Image Similarity Experiments.” *Human Vision and Electronic Imaging III*, 3299(1): 576-590.

[56] Rorissa, A. and Hastings, S. K. 2004. “Free Sorting of Images: Attributes Used for Categorization.” In *Proceedings of the American Society for Information Science and Technology*, 41(1): 360-366.

[57] Rorissa, A. 2008. “User-Generated Descriptions of Individual Images Versus Labels of Groups of Images: A Comparison Using Basic Level Theory.” *Information Processing & Management*, 44(5): 1741-1753.

[58] Rui, Y., Huang, T. S. and Chang, S. F. 1999. “Image Retrieval: Current Techniques, Promising Directions, and Open Issues.” *Journal of Visual Communication and Image Representation*, 10(1): 39-62.

[59] Shatford, S. 1986. “Analyzing the Subject of a Picture: A Theoretical Approach.” *Cataloging & Classification Quarterly*, 6(3): 39-62.

[60] Smeulders, A. W. et al. 2000. “Content-Based Image Retrieval at the End of the Early Years.” *IEEE Transactions on Pattern Analysis and Machine Intelligence,* 22(12): 1349-1380.

[61] Stvilia, B., Jörgensen, C. and Wu, S. 2012. “Establishing the Value of Socially-Created Metadata to Image Indexing.” *Library & Information Science Research*, 34(2): 99-109.

[62] Veltkamp, R. C. and Tanase, M. 2002. “Content-Based Image Retrieval Systems: A survey.” *Department of Computing Science, Utrecht University*, 1-62.

[63] Westman, S. and Oittinen, P. 2006. “Image Retrieval by End-Users and Intermediaries in a Journalistic Work Context.” In *Proceedings of the 1st international conference on Information interaction in context*, 102-110.

[64] Westman, S. 2009. “Image Users’ Needs and Searching Behaviour.” *Information Retrieval: Searching in the 21st Century*, 63-83.

[65] Westman, S., Lustila, A. and Oittinen, P. 2008. “Search Strategies in Multimodal Image Retrieval.” In *Proceedings of the second international symposium on Information interaction in context,* 13-20.

[66] White, H. D. and Griffith, B. C. 1981. "Author Co-Citation: A Literature Measure of Intellectual Structure." *Journal of the American Society for Information Science,* 49(4): 327-355.

[67] Yoon, J. and Chung, E. 2011. "Understanding Image Needs in Daily Life by Analyzing Questions in a Social Q&A Site." *Journal of the American Society for Information Science and Technology*, 62(11): 2201-2213.

[68] Yoon, J. 2009. "Towards a User-Oriented Thesaurus for Non-Domain-Specific Image Collections." *Information Processing & Management*, 45(4): 452-468.

[69] Zhao, D. and Strotmann, A. 2008. "Evolution of Research Activities and Intellectual Influences in Information Science 1996-2005: Introducing Author Bibliographic Coupling Analysis." *Journal of the American Society for Information Science and Technology,* 59(13): 2070-2086.

# [Appendix A] Distribution of publications per journal

| Journal Title | Freq. | % |
|---|---|---|
| Journal of the American Society for Information Science and Technology | 60 | 24 |
| Information Processing & Management | 53 | 21 |
| Journal of the American Medical Informatics Association | 16 | 6 |
| Online Information Review | 14 | 6 |
| Journal of Information Science | 13 | 5 |
| Proceedings of the ASIS Annual Meeting | 12 | 5 |
| Journal of Documentation | 9 | 4 |
| Aslib Proceedings | 9 | 4 |
| Canadian Journal Of Information And Library Science-Revue Canadienne Des Sciences De L Information Et De Bibliotheconomie | 7 | 3 |
| Library & Information Science Research | 6 | 2 |
| Library Hi Tech | 5 | 2 |
| Profesional De La Informacion | 5 | 2 |
| Knowledge Organization | 5 | 2 |
| International Journal of Geographical Information Science | 5 | 2 |
| Program-Electronic Library and Information Systems | 5 | 2 |
| Electronic Library | 4 | 2 |
| Research and Advanced Technology For Digital Libraries | 4 | 2 |
| Information Research-An International Electronic Journal | 3 | 1 |
| Digital Libraries: People Knowledge And Technology Proceedings | 2 | 1 |
| Libri | 2 | 1 |
| Zeitschrift Fur Bibliothekswesen Und Bibliographie | 1 | 0 |
| Social Science Computer Review | 1 | 0 |
| Online & CDROM Review | 1 | 0 |
| Research And Advanced Technology For Digital Libraries Proceedings | 1 | 0 |
| Restaurator-International Journal for The Preservation of Library And Archival Material | 1 | 0 |
| MIS Quarterly | 1 | 0 |
| College & Research Libraries | 1 | 0 |
| Health Information And Libraries Journal | 1 | 0 |
| Australian Library Journal | 1 | 0 |
| Annual Review of Information Science and Technology | 1 | 0 |
| Journal of Librarianship And Information Science | 1 | 0 |
| Journal of Management Information Systems | 1 | 0 |
| Journal of Academic Librarianship | 1 | 0 |
| Human Society and the Internet Proceedings: Internet-Related Socio-Economic Issues | 1 | 0 |
| Information Technology and Libraries | 1 | 0 |
| Total | 254 | 100 |

# [Appendix B] 58 cited authors for author co-citation analysis

| Rank | Cited author | Freq. of citation | Rank | Cited author | Freq. of citation |
|---|---|---|---|---|---|
| 1 | Enser P | 67 | 31 | Ma W | 20 |
| 2 | Jorgensen C | 59 | 31 | Muller H | 20 |
| 3 | Goodrum A | 43 | 31 | Rosch E | 20 |
| 3 | Shatford S | 43 | 34 | Hollink L | 19 |
| 5 | Chen H | 41 | 35 | Jaimes A | 18 |
| 6 | Fidel R | 39 | 36 | Carson C | 17 |
| 7 | Panofsky E | 38 | 36 | Marchionini G | 17 |
| 8 | Armitage L | 36 | 36 | Svenonius E | 17 |
| 8 | Choi Y | 36 | 36 | Wang J | 17 |
| 10 | Smeulders A | 35 | 40 | Gudivada V | 16 |
| 11 | Eakins J | 33 | 40 | Matusiak K | 16 |
| 12 | Chang S | 32 | 42 | Bates M | 15 |
| 12 | Rasmussen E | 32 | 42 | Besser H | 15 |
| 12 | Smith J | 32 | 42 | Krause M | 15 |
| 15 | Markey K | 30 | 42 | Niblack W | 15 |
| 16 | Greisdorf H | 29 | 42 | Spink A | 15 |
| 16 | Hastings S | 29 | 47 | Delbimbo A | 14 |
| 18 | Rui Y | 28 | 47 | Faloutsos C | 14 |
| 18 | Salton G | 28 | 47 | Keister L | 14 |
| 20 | Pentland A | 26 | 47 | Pu H | 14 |
| 21 | Flickner M | 25 | 51 | Ingwersen P | 13 |
| 21 | Jansen B | 25 | 51 | Lainehernandez M | 13 |
| 21 | Oconnor B | 25 | 51 | Robertson S | 13 |
| 24 | Markkula M | 24 | 51 | Trant J | 13 |
| 24 | Swain M | 24 | 55 | Baezayates R | 12 |
| 26 | Gupta A | 22 | 55 | Collins K | 12 |
| 26 | Turner J | 22 | 55 | Jain A | 12 |
| 28 | Ornager S | 21 | 55 | Rafferty P | 12 |
| 28 | Rorissa A | 21 | 55 | Yoon J | 12 |

# [Appendix C] 61 authors for author bibliographic coupling analysis

| Rank | Author | No. of article | Rank | Author | No. of article |
|---|---|---|---|---|---|
| 1 | Chen H | 9 | 31 | Baek Y | 2 |
| 1 | Yoon J | 9 | 31 | Barilan J | 2 |
| 3 | Menard E | 7 | 31 | Cawkell T | 2 |
| 3 | Tsai C | 7 | 31 | Chung C | 2 |
| 5 | Clough P | 6 | 31 | Deserno T | 2 |
| 6 | Goodrum A | 5 | 31 | Fox E | 2 |
| 6 | Jorgensen C | 5 | 31 | Hersh W | 2 |
| 6 | Rafferty P | 5 | 31 | Hwang S | 2 |
| 6 | Rorissa A | 5 | 31 | Jansen B | 2 |
| 10 | Calderaserrano J | 4 | 31 | Kim J | 2 |
| 10 | Choi Y | 4 | 31 | Kiyoki Y | 2 |
| 10 | Enser P | 4 | 31 | Lazarinis F | 2 |
| 10 | Sanderson M | 4 | 31 | Lee M | 2 |
| 14 | Chung E | 3 | 31 | Lin C | 2 |
| 14 | Degoulet P | 3 | 31 | Miller Y | 2 |
| 14 | Iyengar S | 3 | 31 | Muller H | 2 |
| 14 | Jaulent M | 3 | 31 | Neal D | 2 |
| 14 | Kim S | 3 | 31 | Park G | 2 |
| 14 | Lebozec C | 3 | 31 | Ramsey M | 2 |
| 14 | Lee H | 3 | 31 | Rasmussen E | 2 |
| 14 | Lin W | 3 | 31 | Sanchezjimenez R | 2 |
| 14 | Oconnor B | 3 | 31 | Sasaki H | 2 |
| 14 | Pu H | 3 | 31 | Shoham S | 2 |
| 14 | Rorvig M | 3 | 31 | Tjondronegoro D | 2 |
| 14 | Sedghi S | 3 | 31 | Torres R | 2 |
| 14 | Spink A | 3 | 31 | Turner J | 2 |
| 14 | Stock W | 3 | 31 | Wang J | 2 |
| 14 | Yang C | 3 | 31 | Yang S | 2 |
| 14 | Zapletal E | 3 | 31 | Yu X | 2 |
| 14 | Zhang J | 3 | 31 | Zachary J | 2 |
| | | | 31 | Zhu B | 2 |