# Information integration in libraries

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## Abstract

**Purpose** – This paper investigates the latest achievements of studies on industrial information integration engineering (IIIE).

**Design/methodology/approach** – This paper extends the research by Chen (2016) by reviewing studies from 2016 to 2019 in IEEE Xplore and Web of Science. Altogether, 970 papers related to IIIE are grouped into 27 research categories and reviewed.

**Findings** – The results obtained in this study indicate that the number of research studies on IIIE rose drastically in the past three years compared with the findings in Chen (2016). Particularly, energy, engineering, industrial control, information and communications technologies, instrumentation, manufacturing and transportation are the hot topics. This change proves that the Internet of things (IoT) and IIIE have integrated closely by providing more applications, such as industrial Internet of things (IIoT), cyber-physical system (CPS), smart grids and smart manufacturing. This change also proves the research direction of IIIE identified by Chen (2016).

**Originality/value** – The results present up-to-date development of IIIE and provide directions for future research on IIIE. The review identifies that energy, engineering, industrial control, information and communications technologies, instrumentation, manufacturing and transportation are the main fields that most of the reviewed papers focus on. Applications that integrate IoT and IIIE, including IIoT, CPS, smart grids and smart manufacturing, are attracting scholars' and practitioners' attention. Some new technologies, such as 5G and blockchain, have the potential to be integrated with IoT and IIIE.

**Keywords** Information integration, Integration, Library, Digital library, Smart library, IoT, RFID, Big data

**Paper type** Literature review

## 1. Introduction

Libraries disclose and disseminate information, serving as the mediation of access to information (Wójcik, 2016). Physical library collections are valuable resources for knowledge and learning (Yang *et al.*, 2016). At present, reading materials, including text document, image, audio, video and software, are getting more fragmented (Fortino *et al.*, 2014). Managing the inventories of these materials and the space for storing these materials efficiently is a challenge for libraries (Tarique and Priya Rani, 2017; Yang *et al.*, 2016). They are expected to be more productive and highly efficient in collecting, managing and preserving resources and providing specialized services to users by adopting latest technologies. Particularly, time-consuming processes for checking books in and out need replacement. The labor-intensive and time-consuming stock-taking processes need to be automated. The running cost of libraries, the thefts and the number of missing or misplaced items need to be reduced (Markakis *et al.*, 2013).

For libraries, information means locations or objects in geographic space (Doerr and Papagelis, 2007). Traditional tools and methods are not capable of processing fragmented materials. Libraries need integrated access to various information sources with fast deployment and low maintenance cost in a rapidly evolving environment (Christophides *et al.*, 2000). The Internet is changing the way people obtain information (Thanuskodi, 2012). The integration of the Internet allows libraries to utilize new tools and methods for providing information to users (Abdoulaye and Majid, 2000), such as digital resources, mobile service, notification service and ubiquitous service on the basis of traditional service (Fortino *et al.*, 2014). Information integration can help libraries eliminate heterogeneity among different documents, achieve sequential and systematic information resources according to users'

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need, shorten the search time to quickly acquire new knowledge and meet readers' diverse and individual needs (Xue, 2014). Given the role that information integration plays in libraries, scholars and practitioners are exploring the methods to implement information integration. This paper aims to identify current trends of information integration in libraries and to describe challenges that libraries are facing in implementing information integration. By presenting open research questions and future directions of information integration in libraries, this paper also compiles a comprehensive reference list to assist researchers.

## 2. Information integration and libraries

### *2.1 Information integration*

Information is often present in multiple resources, in different locations and formats and within different technologies and electronic infrastructures (Hernandez and Kambhampati, 2004). Information integration refers to combining scattered information into meaningful one for the purpose of providing a uniform access to various data sources (Panetto and Cecil, 2013; Xue, 2014). By promoting resource sharing, collaborative work and effective operation, information integration is one of the most important aspects for accomplishing product development with high efficiency (Hou *et al.*, 2008). Information integration is the essence of data interoperability because it significantly affects the efficiency and effectiveness of decisions (Prajogo and Olhager, 2012). Its goal is to provide an interoperable way for combining information into a coherent view (Lenzerini, 2002).

Aggregating data needs dealing with structural differences, naming differences, semantic differences and content differences (Sujansky, 2001). Complex hierarchical and/or network organization of data, their heterogeneity, complex interrelations, insufficient formalization and incompleteness make it difficult to integrate information resources (Kolpakov *et al.*, 2000). Data warehousing approach and the on-demand approaches are usually adopted for information integration. The former puts all the data together, allowing a quicker, more efficient and effective access to the data, whereas the latter is slower and may only be effective for specific or singular queries (Chicco *et al.*, 2011). Information integration is a pervasive challenge because it can be very difficult to infer new knowledge by integrating data (Hernandez and Kambhampati, 2004).

The integrated information system (IIS) is an array of multiple information sets linked together in an organized way. It involves multiple types of technologies and tools of information and computer sciences and provides a good solution to the complex tasks (Fang *et al.*, 2014; Lin *et al.*, 2012). The integration of systems must be selected to undertake for the purpose of enhancing services, improving service effectiveness and saving time and retrieval costs (Qiu *et al.*, 2010). It is difficult to access accurate data, information and knowledge from different systems because they lack standards for managing data (Shen *et al.*, 2010).

### *2.2 Information integration in libraries*

It becomes more difficult for libraries to provide enough space for storing all necessary information (Bhat, 2018; Hey *et al.*, 2009; Horstmann and Brase, 2016; Simović, 2018). Even though collections of libraries move online at the digital age, libraries still need innovative ways to provide users a comfortable and user-focused space by using their physical space wisely (Norton *et al.*, 2013). Integration of distributed information resources with support services that facilitate locating, retrieving and organizing digital content is the focus of libraries (Mischo, 2001). Information integration in libraries refers to putting the original self-existent information into clusters and combining them based on users' searching needs (Xue, 2014). By organizing information orderly, library information integration aims to

provide users a unified search platform and to help users locate information quickly (Xue, 2014). Libraries are required to have the abilities of collecting, managing and preserving resources and providing specialized services to users. In addition, they need to achieve information reusability and interoperability.

Smart libraries use technological innovation and the Internet to provide users the opportunity for acquiring knowledge via a systematic and multidimensional approach (Baryshev *et al.*, 2015). It provides a smart environment that allows new knowledge creation and mobile access based on new information and communications technologies. At present, the advancements in web services and mobile services have incorporated smart library management systems that allow users to search, browse and query book details via smart phones when they enter the libraries (Saranya and Venkatesh, 2014). Many library services, such as self-borrowing and self-returning, smart inventory, intelligent query, combination of books and information system, can be achieved by IoT (Li, 2013).

Radio frequency identification device (RFID) is a wireless non-contact system that uses radio frequency waves to transfer data from a tag attached to an object (Renold and Rani, 2013; Viriyasitavat *et al.*, 2019). Before RFID is applied with the Internet in library management, libraries are not smart because data collected for virtual objects and physical objects by RFID are not connected and they cannot be used for generating detailed map related to the real situations and decisions (Bayani *et al.*, 2018). Once libraries incorporate RFID and the Internet, they are becoming smart (Bayani *et al.*, 2018). Based on wireless sensors, RFID tags and wireless sensor networks (WSNs), libraries can convert their process into an intelligent system and achieve automatic identification and tracking. Book monitoring, registering and inventory control can be automated to perform them and self-checking in/out and detecting automatically as well as in an efficient manner (Bayani *et al.*, 2018). Each material in a smart library is embedded a near-field communication (NFC) tag. Racks are provided with rack monitors containing NFC readers connected to WLAN. When a material is placed in a rack, the rack monitor reads the information of the material through the NFC tag. The information is then stored in the smart library's database (Brian *et al.*, 2014). Therefore, RFID and the Internet can improve library management in adding books, issuing books, managing late return, tracking books (Tarique and Priya Rani, 2017), locating the misplaced or misshelved book or materials, reducing the manual work and ease access of the books (Antevski *et al.*, 2016; Renold and Rani, 2013). In addition, massive literature data can be loaded into library management system through RFID (Hossain *et al.*, 2018). RFID-based smart libraries can be improved by maximizing tag readability, localizing tagged items in smart bookshelves and reducing spill-over energy to nearby shelves (Markakis *et al.*, 2013).

## 3. Recent studies on information integration in libraries

Achieving interoperability for different representations of the same or related entities between the library and other institutions can enhance rich bibliographic data reusability and support the development of new data-driven information services (Zapounidou *et al.*, 2017). Scholars and practitioners are exploring approaches to achieve information reusability and interoperability. Extensible Markup Language (XML) has become a key language for information interchange and integration over the World Wide Web (Heumesser *et al.*, 2003). HTML widget-based techniques, such as Google Book Classes, Tictoclookup and MAJAX, can promote library information integration without requiring programming experience or expensive hosting (Back and Bailey, 2010). Alewaeters *et al.* (2000) develop integrated access to electronic documents and information in different formats. Christophides *et al.* (2000) propose an algebraic approach to support efficient XML query evaluation. Marcum (2001) proposes a discovery system model to guide technology integration in libraries. Mischo (2001) points out that XML and digital object identifier will play prominent roles in improving access and

retrieval over heterogeneous digital resources. Cai (2002) proposes an integrated and flexible geographic information retrieval and browsing tool. Yagüe *et al.* (2002) present a system that provides distributed access control and secure content distribution for digital libraries. Guan *et al.* (2003) propose the MAG2DL framework for retrieving information and integrating distributed geographic digital libraries with mobile agent and GML technologies. Lee (2003) proposes a knowledge network approach to implement a distributed digital library. Lu *et al.* (2003) propose a client-server-based query translation approach to achieve more feasible implementation of cross-language information retrieval services in digital library. Weaver *et al.* (2003) present an architecture for combining spatial reasoning and selection with traditional (non-spatial) search. Yagüe *et al.* (2003) present the XML-based secure content distribution infrastructure for integrating privilege management infrastructures. Ciravegna *et al.* (2004) present a methodology, which is based on a combination of information extraction, information integration and machine learning techniques, for harvesting information from large distributed repositories. Song *et al.* (2005) propose Clustering-based Opaque Schema Matching (COSM), an algorithm to automatize the web data schema-matching process. Lamy (2007) presents a method to integrate digital topology information in image-processing libraries. Barros *et al.* (2008) develop a digital library-based environment to support the integration, dissemination and exploration of ecological data. Ivanyukovich *et al.* (2008) present an information extraction pipeline from digital document acquisition to information extraction, processing and management. Shen *et al.* (2008) propose an approach for integration in digital library based on streams, structures, spaces, scenarios and societies. Twidale *et al.* (2008) investigate the potential of a tighter integration between searching for information in digital libraries and using those results in academic writing. Virkus (2008) points out that integration of information and communications technologies into library and information science education is a challenge. de Campos *et al.* (2009) present an information retrieval system for structured documents and integration of multimedia sources. Sens and Bluemel (2009) develop a project Prototypical Operation of Common Documents for automated indexing, storing, searching and retrieving non-textual media. He *et al.* (2010) integrate digital library technologies with ontology-based knowledge representation for providing semantic-rich information access. Kao and Wu (2012) propose a personalized information and knowledge integration platform for digital library (PIKIPDL), which can suggest materials for readers and construct knowledge contents in a hierarchical structure. A next generation of intelligent information systems will be based on intelligent technologies and applications in the digital library area, as well as on progress toward improved quality and integration. Leidig and Fox (2014) propose a SimDL framework, which generates simulation-supporting digital library instances, for automating routine tasks and improving intelligent services in digital libraries. De Beer *et al.* (2016) present a method called alternate reality games for gathering, integration and analysis of digital information sources. Latif *et al.* (2016) assert that there is a strong relationship between linked open data (LOD) in libraries and artificial intelligence, databases and knowledge discovery. They further review LOD in digital libraries and discuss the current LOD research topics, including data and schema integration and distributed data management. Raieli (2016) argues that multimedia information retrieval offers a better information searching way because it is composed of content-based and semantic information retrieval methodologies. Zapounidou *et al.* (2017) propose to study the representation of monographs, content relationships and whole-part relationships between them for enabling semantically richer interoperability.

## 4. Discussions

Chen (2016) points out that there are a growing number of research studies on the issues, challenges and solutions related to the design, implementation and management of industrial information integration. The advances in industrial information integration methods have

spurred tremendous growth of a variety of techniques that have been used for probing industrial information integration (Chen, 2017; Gorkhali and Xu, 2019; Li *et al.*, 2018; Xu, 2015; Xu *et al.*, 2018), particularly IoT and cloud computing.

IoT has been widely applied in healthcare, supply chain, logistics, mining, transportation, firefighting, intelligent home, building automation, smart grids, smart city, energy management and asset tracking (Lu, 2018a, b; 2019a,b; Perett, *et al.*, 2015; Rashid, Melià-Seguí *et al.*, 2016; Srinivasa *et al.*, 2018; Whitmore *et al.*, 2015; Xu, 2011; Xu *et al.*, 2014). In recent years, applications of IoT have expanded from industries to education. Colleges and universities are actively constructing wisdom campus based on IoT to ensure digital resource integration and sharing, including campus personnel identification, library management, campus ID, student management, teaching environment management in class and the management of teaching instruments and equipment (Wang, 2014; Zhao, 2013; Zong *et al.*, 2014).

Cloud computing is "a model for enabling ubiquitous, convenient on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Gorkhali and Xu, 2016; Mell and Grance, 2011, p. 2). Together with IoT, cloud computing has been widely adopted in industries. Similar applications are expected in libraries. Future research should explore effective approaches to integrate IoT and cloud computing with libraries. Humanities, technology and economic factors should be considered in the integration (Qiu *et al.*, 2010).

A next generation of intelligent information systems will be based on intelligent technologies and applications in the digital library area, as well as on progress toward improved quality and integration (Leidig and Fox, 2014). Moreover, the integration of diverse Web 2.0 tools can improve the information services in libraries as well because information is organized and standardized by social reference managers and subsequently disseminated among users through social networks (Alonso Arevalo *et al.*, 2014).

Integration of library data into the semantic web environment is another key issue for libraries. Schema matching is a basic problem for heterogeneous data source integration (Song *et al.*, 2005). Song *et al.* (2005) point out that there are two challenges for web information integration: web data are short of intact schema definition; and the schema matching between web data cannot be simplified as 1-1 mapping problem.

Security is the main issue for many automated library systems. Distributed access control and secure content distribution are the two important security issues (Yagüe *et al.*, 2002). For smart libraries, vulnerability in IoT devices, operating system or software can be exploited by cybercriminals (D'Orazio *et al.*, 2017). Due to the extremely constrained resources in libraries, incorporating security protocols in IoT components is challenging (Arafin *et al.*, 2017). Therefore, security is the main challenge to promote IoT in libraries. The applications of RFID in authentication are limited because of RFID tags' low resource feature (Wei *et al.*, 2014).

## 5. Conclusions

The volume, velocity and variety of big data make it difficult to extract useful information from massive data. For processing big data, information integration is an effective approach to achieve efficiency. This paper aims to identify current trends of information integration in libraries and to describe challenges that libraries are facing in implementing information integration. By presenting open research questions and future directions of information integration in libraries, this paper also compiles a comprehensive reference list to assist researchers.

For libraries, information integration is required to provide new tools and methods for serving users as well as reduce maintenance cost. Intelligent technologies and Web 2.0 tools

are available for digital libraries. In addition, information reusability and interoperability are the new goals for digital libraries. Security is still a major concern in information integration for libraries.

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