2011

The application of intelligent agents in libraries: a survey

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The Application of Intelligent Agents in Libraries: A Survey

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Abstract

Purpose – To provide comprehensive literature review on the utilisation of intelligent agent technology in the library environment.

Design/methodology/approach – Research papers since 1990 on the use of various intelligent agent technologies in libraries are divided into two main application areas: (1) Digital Library (DL), including agent-based DL projects, multi-agent architecture for DLs, intelligent agents for distributed heterogeneous information retrieval and agent support to information search process in DLs; and (2) services in traditional libraries, including user interface for library information systems, automatic reference services and multi-agent architecture for library services. For each paper on the topic, its new ideas or models, referred work, analyses, experiments, findings and conclusions are addressed.

Findings – The majority of the literature covers DLs and there have been fewer studies about services in traditional libraries. A variety of architecture, framework and models integrating agent technology in library systems or services are proposed, but only some of them have been implemented in the practical environment. The application of agent technology is still at the research and experimentation stage. Agent technology has great potential in many areas in the library context; however it presents challenges to libraries which want to be involved in its adoption.

Practical implications – The survey has practical implications for libraries, librarians and computer professionals in developing projects which employ intelligent agent technology to meet end users' expectations as well as to improve information services within limited resources in library settings.

Originality/value – The paper provides a comprehensive survey on the development and research of intelligent agents in libraries in literature.

Keywords – Intelligent agents; Artificial intelligence; Libraries; Library services; Digital libraries; Library systems

Paper type – Literature review

Word length: 9584

1. Introduction

Modern libraries have evolved from centralised, paper-based systems into distributed networks of digital and non-digital materials, providing innovative library services as well as traditional services. With the dramatic increase of available materials and user expectations, libraries are forced to exploit new technology to fulfil their missions with relatively limited resources. Intelligent agent technology, a rapidly developing research area, has the potential for libraries.

In Computer Science, intelligent agents often refer to software systems which are able to take actions towards their goals without human intervention. An intelligent agent may have the ability of reasoning, planning, learning and collaborating with users or other agents in various environments. The intelligent agent technology has been adopted in many areas, including industrial control, medical diagnosis, stock trading, personal assistance, games, scientific discovery and information retrieval, etc. This survey covers

research on the application of intelligent agent technology in the library environment since the 1990s. Research projects and papers were identified using sources such as Google Scholar, the Association for Computing Machinery (ACM) Digital Library, the Institute of Electrical and Electronic Engineers (IEEE) Xplore, and researchers' websites, etc. No doctoral work in this area was found in literature, and only one masters dissertation was identified. The majority of the identified work is about the use of intelligent agents in Digital Library (DL), including main DL projects funded by government bodies in different countries. These projects adopt agent technology as underlying architecture to support information search and retrieval in DLs. Many papers in literature are related to these projects, either directly resulting from them or referring to them. These papers can be divided into three sub-categories:

- Multi-agent based architecture for DLs. Papers in this sub-category emphasize on constructing a DL which is able to support large amounts of digital content organization and decentralised service delivery.
- The use of agent technology for information retrieval from distributed sources. This sub-category is mainly about retrieving heterogeneous, distributed information in federated DLs.
- Agent support to information search process in DL environment, including strategic search support, proactive search support and intelligent assistance to information search and retrieval, etc.

Only a few research papers address the application of intelligent agent technology for services provided in traditional libraries. In contrast to DLs, traditional libraries in this survey refer to physical library settings where librarians and library staff perform tasks

and provide services to end users. A traditional library usually contains both print and digital content, physical and electronic services. Existing research in this category includes agent-based user interface design for library information systems, automatic reference services by agents, and multi-agent models for library services. The literature review also identified a conceptual paper on agent technology in modern libraries from a librarian's perspective. It provides background information as well as case studies for agent application in areas relevant to library and information settings. In addition, a general review paper presents application examples of intelligent agents in different contexts and their possible application in fulfilling a wide range of library tasks and services.

2. Background

The concept of intelligent agents belongs to the field of Artificial Intelligence, a branch of Computer Science (Poole et al, 1998). The idea of intelligent agents was introduced in the mid-1950s, and they have been defined in many ways. From the perspective of building an agent, Russell and Norvig (2003) define an agent as "anything that can be viewed as perceiving its environment through sensors and acting upon the environment through actuators" (p. 32). This definition emphasizes computational intelligence of agents. Maes (1995) states that "agents are computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed" (p. 108). The statement indicates that an agent is goal-oriented and the environment is complex. Wooldridge and Jennings (1995) describe an agent as a computer system that is "either

conceptualised or implemented using concepts that are more usually applied to humans" (p. 5). Although no definition for intelligent agents has been universally accepted (Dent, 2007), there is a broad consensus that agents should have the property of autonomy. They may also have other attributes, such as social ability, reactivity, pro-activeness, rationality and mobility, etc. (Wooldridge and Jennings, 1995). Intelligent agents can be classified from different perspectives. According to their intelligence degree, agents are classified into: reflex agents, goal-based agents, utility-based agents and learning agents (Russell & Norvig, 2003). Based on their functionality, intelligent agents are categorized to the following types: collaborative agent, reactive agents, mobile agents, interface agents, Internet agents, etc. (Hostler et al., 2005).

Russell and Norvig (2003) introduce the basic concepts of intelligent agents, including knowledge representation and reasoning, planning, decision-making and problem solving. They also present example agent systems in the areas of autonomous planning and scheduling, game playing, autonomous control, diagnosis, logistics planning, robotics, language understanding and problem solving. The book is widely adopted as the textbook by many undergraduate and graduate computer science and engineering courses around the world. Klusch et al. (2003) provide introductions and surveys on agent-based information systems and the information agent, a concept more relevant to the library world. According to this book, an information agent is capable of accessing, acquiring, mediating and maintaining information in a distributed networked environment on behalf of human users or other agents. There are several classes of information agents, such as rational agents, adaptive agents and mobile agents. A rational agent is capable of making decision rationally on when and how to take actions; an

adaptive agent has the ability to adapt to changes in its environment; and a mobile agent is able to travel the network to perform tasks in a remote site (Klusch, 2001).

The applications of intelligent agent technology are well documented in literature from a computer science or engineering perspective, but not from a library perspective. Dent (2007) appears to be the first librarian to review the research on the use of artificial intelligence in areas relevant to information settings. The author refers to a variety of papers and books from 1988 to 2006 on the concept of agent technology and its applications in web-based environment. This paper covers the areas of search engines, the online shopping market and support for teaching and learning. The author also studies three practical application cases of agent technology in library settings: the University of Michigan Digital Libraries (UMDL) project, the project Managing the Hybrid Library for the Benefit of Users (MALIBU) and the Distributed Agents for User-Friendly Access of Digital Libraries (DAFFODIL). Information professionals play a key role in the agent-based system development and implementation in all these cases. In addition, the paper presents an agent-based conceptual model for personalised information environment. The author claims that intelligent agent technology has potential in many library areas, such as information literacy, virtual reference, collection management, user search support and uses for routine tasks. The paper concludes that agent technology has both technical and social implications to libraries and librarians, including conceptualising appropriate uses of agent technology, and the development and implementation process of agent technology in library and information systems. Lohani and Jeevan (2007) introduce the concept, attributes and different types of intelligent agents, as well as their application areas and examples, such as personal assistants, visitor hosting systems, data mining,

network management and air/land traffic control. The paper also discusses the potential use of intelligent agents for a variety of library services and tasks, including electronic information services, collection development and acquisition, library material classification, indexing and abstracting, circulation and reference services, etc. The authors claim that it is feasible to apply intelligent agents in various contexts to improve information organization and library services.

3. Intelligent agents in DLs

3.1 Agent-based DL projects

There are three major agent-based DL projects conducted in the US, the UK and Germany respectively. Many papers in literature are based on these projects or refer to them.

The UMDL project is sponsored by the National Science Foundation (NSF), Advanced Research Projects Agency (ARPA) and the National Aeronautics and Space Administration (NASA). According to its website, the project started in 1994 and the latest work was published in 1998 (University of Michigan). A multi-agent architecture is proposed to provide access to information in different multimedia formats. The architecture also supports automatic completion of administrative tasks (Birmingham, 1995).

The MALIBU project is part of the Electronic Libraries Programme (eLib) project in the UK which is funded by the Joint Information Systems Committee (JISC). It has three major partner institutions, including King's College London, Oxford University and Southampton University. The project timeline is 1998-2001 (eLib Programme Office,

1998). It aims to provide access to both print and electronic resources within a union framework. A multi-agent architecture is implemented in the search engine prototype. It allows users to search for and retrieve a variety of digital and non-digital, internal and external resources using a single interface. The architecture supports distributed development, agent interaction and system maintenance (Dent et al, 2001).

The DAFFODIL is a search interface project for DLs funded by the German Research Foundation (DFG). The project timeline is from 2000 to 2004, but the most recent paper on the project website was published in 2009 (Daffodil, 2009). The project aims at providing strategic support for users to search and retrieve information in DLs.

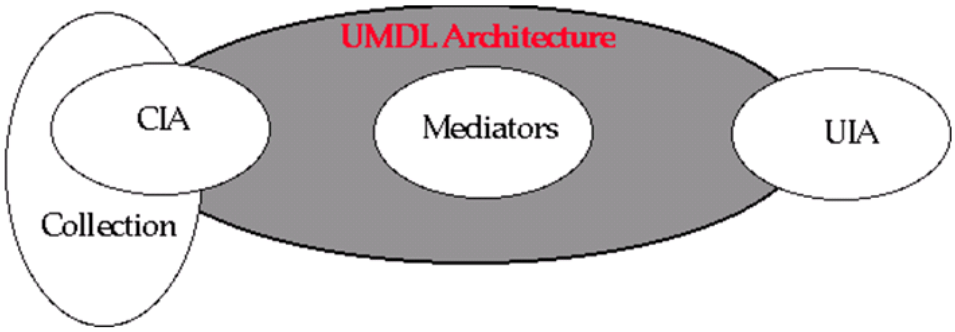
3.2 Multi-agent architecture for DLs

Multi-agent systems for DLs have been proposed by many papers in literature. Most of these papers were published in the late 1990s and based on work completed by researchers from the US, Mexico and the UK.

Birmingham (1995) appears to be the first to identify the need for software architecture to federate multiple DLs. The author suggests that the agent properties of autonomy and negotiation make the agent-based architecture suitable for the UMDL project, as shown in Figure 1.

Take in Figure 1

Figure 1. UMDL agent types (Birmingham, 1995)



In the architecture, an agent represents a collection or a service in the library. There are three classes of agents: UIAs (User Interface Agents); Mediator Agents; and CIAs (Collection Interface agents). The UIA provides a communication wrapper around a user interface. It formats queries in the proper form, and sends the user's profile to mediator agents to guide the search process. There are two types of mediators: registry agents and query-planning agents. These agents work together to perform many functions, for example, referring the initial requests or transmitting search results. Similar to UIAs, the CIAs provide a communication wrapper for collections.

The architecture has been implemented in the UMDL which includes approximately 50 CIAs and supports basic searches. The author claims that it supports task decentralisation and is feasible, scalable, extensible and modular. It is the milestone architecture for DLs and has been cited by many later studies in literature.

Sanchez and Leggett (1997) propose the AGS, agent services architecture for DLs. They introduce the concept of agent services which are defined by publishers or librarians and subscribed by users. The authors adopt the server/client structure in the AGS architecture. The AGS is composed of Active Library Service, User Agent Management and User Agent Director. A prototype of the architecture has been implemented. Based on the experiments conducted on the prototype, the authors claim

that the architecture is feasible and applicable. This paper suggests that future work focuses on producing agents with diverse functions and using agents in the construction of a DL.

In 1997, Ferguson and Wooldridge present the Zuno Digital Library (ZunoDL) framework which consists of agents representing consumers, producers and facilitators. Consumers are realized as User Interface Agents which interact with library end users. Producers include Library Service Agents and Catalogue Agents which correspond to information providers. Search Agents represent facilitators which act like brokers between consumers and producers. Two products have been created from this project: the Zuno Digital Publisher and a client-side User Interface Agent. The authors claim that the framework is decentralised, domain independent and designed as information economy.

The abovementioned architectures are quite similar in terms of their basic structures: they all have different types of agents working with the resources, the users and the mediation of agents and tasks respectively.

3.3 Intelligent agents for information retrieval in DLs

A number of research papers examine the use of agent technology to provide support to heterogeneous, distributed information search and retrieval in federated DLs, including information retrieval in the hybrid library, web-based information retrieval, mobile agents for remote information retrieval and processing, ontological agents for heterogeneous information retrieval, and the interoperability of distributed information retrieval. All proposed solutions are based on multi-agent systems. Most papers are completed by researchers from institutions in the UK, Canada, Mexico, Italy, China, and the US.

3.3.1 Information retrieval in the hybrid library

Dent et al. (2001) introduce the agent technology, GIGA (Global Information Gathering Architecture) which was used in the MALIBU prototype supporting the hybrid library. There are both digital and non-digital resources available in the hybrid library. Different from previous search engines, the GIGA supports heterogeneous information search and retrieval in a distributed environment. The GIGA architecture is an improvement on the work of Wiederhold (1991). It adds a brokerage layer, the meta agent for agent interaction and resource control to the original structure. The paper also adopts the key-value representation for the ontologies and sub-ontologies to lessen the overhead and simplify the development and implementation.

The search engine has been implemented and tested in three institutions in the UK. The users' feedback indicates that it is useful to apply intelligent agent technology to search engines for the hybrid library. The authors claim that the agent architecture of the GIGA has various advantages compared to traditional search engine architecture in terms of agent interaction, distributed development support and system maintenance, etc. They conclude that agent technology has many implications for the hybrid library environment.

3.3.2 Web-based information retrieval

Detlor and Arsennault (2002) investigate the use of intelligent agents in seeking and retrieving web-based library information based on the following work:

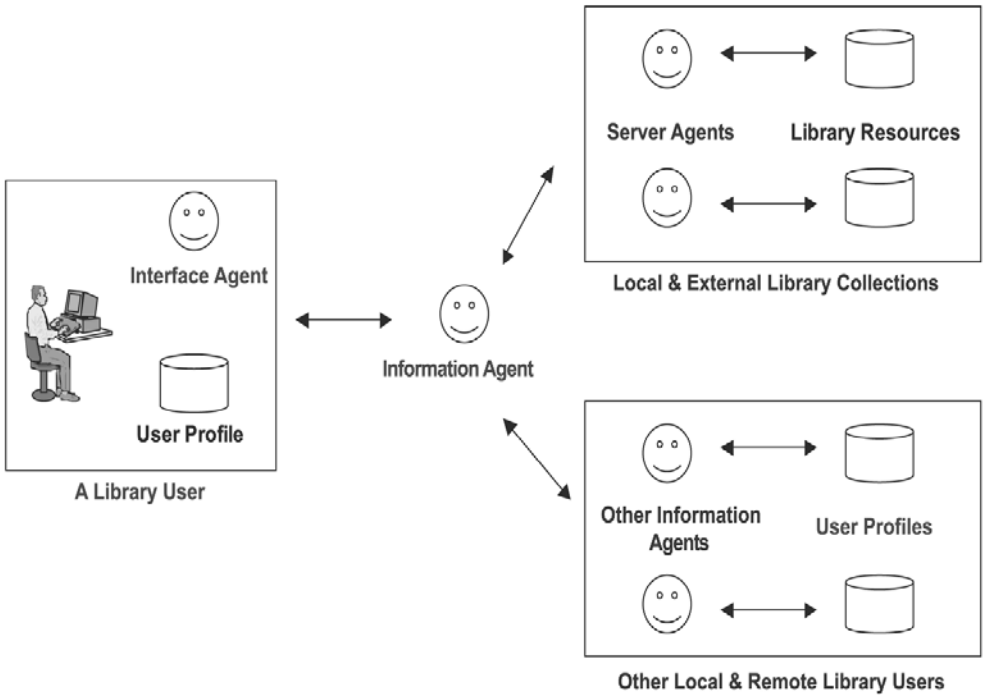
- interface agents providing personal assistance to users based on their information search behaviour and preferences, such as news-editors and information filters (Maes, 1994; Nwana & Ndumu, 1999);
- information agents performing information-laden background tasks, such as web indexing spiders and crawlers (Nwana & Ndumu, 1999);
- interface agents supporting the web-based information browse and search by Choo et al. (1998; 1999; 2000) and Detlor & Sproule (2002).

However, none of the above work integrates the different types of agents into one system. The authors further refer to the agent-based architecture of DLs, including the UMDL (Birmingham, 1995) and the ZunoDL (Ferguson & Wooldridge, 1997). The limitation of these architectures is that they are only designed for specific library environments.

Based on the referred work, Detlor and Arsenault (2002) propose a generic multi-agent model for information seeking and retrieval as illustrated in Figure 3.

Take in Figure 3

Figure 3. An agent-based model of information seeking and retrieval for library contexts (Detlor & Arsenault, 2002, p. 406)



In the model, an individual user has a personal interface agent. The interface agent monitors the user's information seeking behaviour and provides assistance to the user. The information agent serves as an information intermediary. The server agents fulfill the requests from the information agents on specific collections. These agents collaborate to help users retrieve information. The authors claim that the model enhances the web-based information seeking and retrieval and can be expanded to incorporate other types of intermediary agents in the future.

3.3.3 Mobile agents for remote information retrieval and processing

The use of mobile agents for distributed information retrieval and processing has been addressed in many studies. Dale (1997) presents a framework using mobile agents to move across distributed computing environments and interact with other agents and human users. Wook et al. (2001) propose the Timed Mobile Agent Planning scheme to

retrieve information from distributed places. These studies, however, do not focus on library settings.

Sanchez et al. (2002) propose the Mobile Agents in Digital Libraries (MAIDL) framework which incorporates mobile agents to support the information retrieval from a set of heterogeneous, distributed DLs. The MAIDL framework includes:

- mobile agency: providing an execution environment for mobile agents;
- mobile agents: moving across network nodes for users to access local as well as distributed information resources;
- Open Archive Initiative (OAI) protocol server: supporting the metadata harvesting protocol;
- information retrieval services: locating information and determining its relevancy for mobile agents.

A prototype based on the proposed framework has been implemented and tested. The experiment results indicate the performance of the system is acceptable to users. The authors claim that the proposed framework is practical to use mobile agents to retrieve distributed information from federated DLs. They indicate that future work focuses on facilitating inter-agent communication and adopting advanced methods, such as user profiles, site load and network metrics.

Yang et al. (2002) identified the practical problem of processing and retrieving large datasets which are created at geographically distributed remote places. The authors refer to a number of DL projects, including the UMDL (Birmingham et al., 1995), the University of California at Berkeley DL Project (Wilensky, 1995), the Alexandria DL (Andresen et al., 1998), the Carnegie Mellon information digital video library project

(Christel and Martin, 1998), the University of Illinois at Urbana-Champaign (UIUC) DL project (Bishop, 1998), the Stanford DL Project (Paepcke et al., 1999), the DigiTerra at Rutgers University (Adam et al., 2000), and the Virtual Community Library ((Rasmusson et al., 1998).

Based on these projects, the authors propose an agent-based framework utilising mobile agents as well as stationary agents to support data processing in DLs. They indicate that this approach is particularly useful when data migration cannot be achieved. The framework has been implemented in the Synthetic Aperture Radar Atlas (SARA) remote-sensing library. There are two types of agents in the SARA system: one is the user interface agent, including user request agent and user presentation agent; another is the local interface agent, including local assistant agent, local management agent, local integration agent, local retrieval agent and local security agent. The system uses XML schema for agent communication. The authors claim that the framework is capable of supporting large dataset management and parallel queries as well as providing an XML-based data model for the distributed data integration. Further information is provided by Yang et al. (2005).

3.3.4 Ontological agents for heterogeneous information retrieval

Ontologies have been adopted for information retrieval and processing in a number of projects. Pomerantz & Silverstein (2001) develop ontologies to address the problem of semantic heterogeneity in distributed information retrieval. Fensel (2001) uses ontologies and agents in the semantic web project for heterogeneous information access. Saavedra (2003) utilises ontologies to merge different databases at run time. However all these

projects focus on the areas of knowledge management and electronic commerce rather than libraries.

In 2004, Medina et al. propose a multi-agent architecture which integrate ontological agents for the support of information retrieval in DLs. Ontologies are used to expand queries and avoid keyword ambiguity. Their paper is based on the previous work of the Virtual Reference System (Sanchez et al, 2001) and reference agents for DL information retrieval (Medina et al, 2002; 2003). The architecture presented in this paper composes reference agents, ontological agents and mobile agents. Reference agents are a type of user interface agent which interact with the system and the users. Mobile agents are network agents which visit and retrieve resources. There are two types of ontological agents in the system, including Natural Language Processing (NLP) agents and source descriptor agents. NLP agents are used to eliminate query ambiguity. Source descriptor agents describe the heterogeneous schema for the sources. The authors claim that ontological agents are useful to improve information retrieval in DLs. The ontological agents are designed based on Gaia methodology (Wooldridge et al., 2000). This paper indicates that the design methodology has benefits in agent implementation, system maintenance, validation, verification and test.

3.3.5 Interoperability of distributed information retrieval

Shi et al. (2007) address the interoperability of heterogeneous information sources. They refer to the work of the Stanford InfoBus (Paepche et al., 1999) which constructs services as distributed objects in an interface. They also refer to various projects based on the mediator/wrapper architecture (Garcia-Molina et al., 1997; Liu et al., 2000; Chau et al.,

2001). However, previous studies do not provide a uniform format for the presentation of information acquired from distributed heterogeneous sources and most of them use Extensible Markup Language (XML) for agent communication.

The authors propose an agent-based mediation architecture to provide integrated information retrieval services in federated DLs. The architecture adopts the Resource Description Framework (RDF) as the agent communication mechanism to overcome the shortcomings of XML. They realise an instance of the architecture and demonstrate an information retrieval scenario in the instance. The authors claim that the architecture supports the federated DL interoperability. They indicate that future work improves the interface description document for complicated sources and creates an automatic maintainer for interface description in the architecture.

Besides this paper, the idea of combining RDF with agent-based architecture for the interoperability in DLs is also presented by Fuhr and Klas (2001) and Liu et al. (2007).

3.4 Agent support for information search process

Agent technology has been used to support the information search process in DLs, including strategic search support, proactive support for query formulation, intelligent assistance to information search and retrieval and personalised services to users. Most papers are completed by researchers from institutions in Germany and Canada.

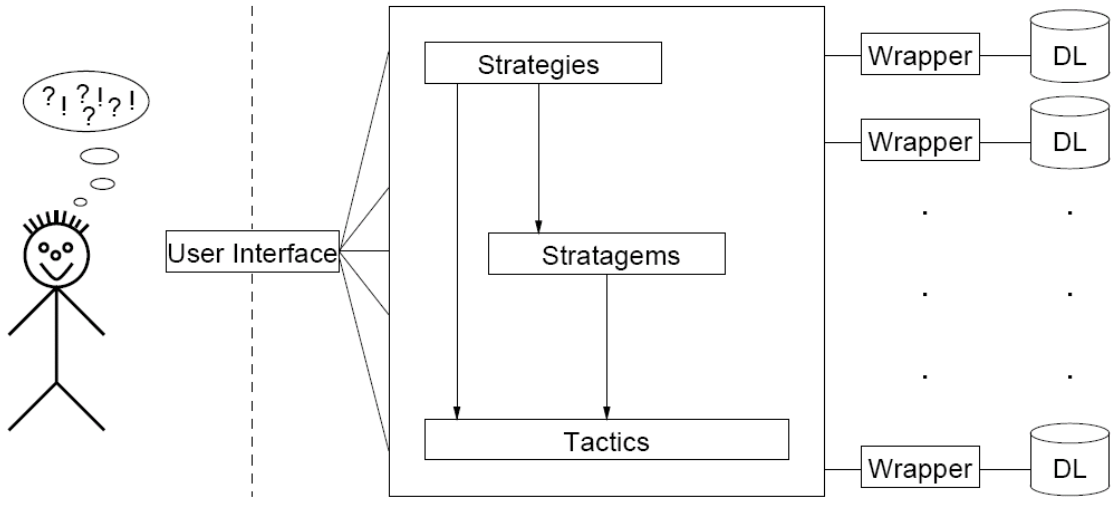
3.4.1 Strategic search support

Bates (1990) introduces the concept of information search stratagem and identifies four levels of search activities: move, tactic, stratagem and strategy. It is desirable for federated DLs to support both low-level search activities (moves), and high-level activities (tactics, stratagems and strategies) (Fuhr et al, 2000). Previous research has addressed the different aspects of information retrieval of distributed resources: database selection (Gauch et al, 1996; Fuhr, 1999a); collection fusion (Callen et al, 1995; Voorhees et al, 1995; Baumgarten, 1999); heterogeneity with regard to database schemas and search predicates (Chang et al, 1999; Fuhr, 1999b); and architectures for federated DLs (Frew et al, 1998). All work, however, takes system-oriented approaches which do not support strategic search activities.

Fuhr et al. (2000) propose an agent-based architecture for the support of high-level search activities in federated DLs combining the advantages of previous approaches (see Figure 2).

Take in Figure 2

Figure 2. Overall architecture (Fuhr et al, 2000, p. 251)



In the architecture, the user interface consists of the windows of query, attribute values, result list, documents and messages. The strategies provide a pre-search interview with users. A stratagem is an action set containing different tactics. The authors create a test-bed in the subject of computer science. It contains about 12 DLs containing different types of resources, for example: table of contents, reference databases, citation databases and full-text databases. A system based on the proposed architecture is implemented comprising wrapper agents, stratagem agents and user interface agents. It includes stratagems of author search, subject search, plain search, area scan and browse. Users can access to the system via a Web browser. The authors claim that the proposed architecture is the first system integrating searching and browsing functions in DLs and supporting the high-level search activities.

3.4.2 Proactive support to query formation

Schaefer et al. (2005) examine the problem to provide proactive support to query formation in distributed information retrieval in DLs. The authors refer to the following studies:

- the concept of system support in information search process, such as suggesting corrections, additions or substitutions to a term (Bates, 1989);
- term suggestions in initial query formulation (Schatz et al., 1996);
- suggestions, terminology and strategy help for query reformulation (Brajnik et al., 1996);
- support for users' query formulation, correction and completion in search engines, such as Google Suggest, Altavista and Scirus.

The authors present a method to provide proactive support to users, including error markers and term suggestions for their queries. They design error markers using symbolism and correction suggestions using a pop-up list of co-occurring terms. An observer agent is implemented along with several modules, including query history module, related-term module and thesaurus module. The observer agents watch queries and provide proactive support to users. The method has been evaluated through three different types of user tests, including heuristic evaluation with mock-ups, controlled tests and single user 'loud thinking' tests. Based on the experimental results, the authors claim that the method reduces the uncertainty in query formulation and thus increases users' satisfaction with information systems. They indicate that future work is to continue to evaluate whether the proactive functions are able to facilitate users in their information search process or not.

3.4.3 Intelligent assistance to information search and retrieval

Pelletier et al. (2003) address the problem of providing intelligent assistance to users when they search and retrieve information from disparate sources. The authors refer to the architectural concepts by Lander and Lesser (1994) and the UMDL project (Birmingham, 1995). A multi-agent framework, the ISAME, is proposed to create an environment supporting the collaboration and cooperation among a variety of types of agents. A virtual library based on the ISAME contains agents which have access to distributed heterogeneous resources and services which assist users in the information search process. The framework supports the following types of agents: User Agents, Information Agents, Request Agents and Support Agents. The Support Agents include

Communication Broker Agent, Registry Agents, Source Filter Agent and Result Filtering Agents. The Knowledge Query and Manipulation Language (KQML) is used for inter-agent communication. The authors also apply a hybrid technique using mailboxes and messengers to solve the problem inherent to blackboard techniques.

The architecture has been partially implemented. Based on the analysis on the implementation results, the authors claim that the ISAME make distributed resources transparent to users and thus simplify the information retrieval process. They also claim that the structure of the ISAME is open to new agents representing new users or sources. The paper indicates that future work continues to elaborate the architecture, to consider the short-term and long-term information preservation and to establish the inter-connection among multiple ISAME environments.

3.4.4 Personalised services

DLs usually provide multiple access points and query forms but little personalised services. This sub-section includes studies offering personalised, adaptive services to end users when they search information in DL systems.

Kriewel and Fuhr (2007) address the problem of providing strategic help to end users in information retrieval systems. They refer to previous work as follows:

- the collaborative coaching system which is able to provide suggestions to users (Brajnik et al., 2002)
- the mixed-initiative system providing users strategic help in the information search process (Belkin et al., 1993)

- the MERIT system which utilises the case-based reasoning (CBR) techniques to instruct users seeking information (Belkin et al., 1995).

Based on these studies, the authors present a tool, the Adaptive Support for Digital Libraries (ASDL), which is able to provide strategic help to end users during their search process in DL systems. The tool adopts CBR techniques to provide and rank suggestions. The tool is developed and implemented in the DAFFODIL framework and is able to learn from user participation. The ASDL module consists of Observing Agents (OAs), Reasoning Agents (RAs) and Suggestion Tool (ST). The OAs collect information about current search activities and search results; the RAs retrieve and rank suggestions based on current search situation and its similarity with previous scenarios; and the ST presents and adapts suggestions. The authors conduct a pilot study to evaluate the ASDL prototype and claim that the preliminary results indicate a high acceptance of the tool by users. They state that future work includes further evaluations on the suggestion ranking and the determination of a stop point for suggestions, as well as extending the suggestion tool from single tactics and stratagems to action sequences or paths.

Klas et al. (2008) present an architecture for adaptive services in DL environment. The authors refer to the concept model by Landwich et al. (2008) and the ASDL tool. They indicate that the concept model is able to capture the information context of users' queries and to provide strategic help to users during their information search process. However, both the model and the ASDL tool focus merely on one aspect of adaptive services. Klas et al. (2008) introduce a generic classification of adaptivity for information systems. The classification includes adaptive system services, adaptive content services and adaptive user services. An adaptive service model is also proposed for the support of

personalisation and adaptive suggestions in DLs. Three scenarios for adaption and personalisation are identified, including information retrieval, user interface and adaptive suggestions. The authors indicate that future work focuses on identifying further possible adaptive services as well as capturing and analysing the interactions between users and systems.

4. Intelligent agents for services in traditional libraries

4.1 User interface for information systems

A master work by Ahad (2005) is identified on the agent-based user interface design for library information systems. It refers to a variety of previous studies, although none of them is used in library systems, including:

- agents using non-verbal techniques for social interaction (Bickmore and Cassell 2001; Jung et al., 2005)
- interface agents for virtual host, guide and helper (Persson, 1999; Erno et al., 2002; Isbister et al., 2000; Ishida, 2002; Canamero and Gaussier, 2005; Michael et al., 2005)
- tangible user interface using Radio Frequency Identification (RFID) technology by the Massachusetts Institute of Technology (MIT) Media Lab (Hiroshi and Brygg, 1997).

The author introduces the concept of using virtual human characters to support user personalisation in library systems which is realised through the development of a personalised library assistant prototype, the Neva. Based on embodied conversational agent technology, Neva integrates a number of features and ideas in the above mentioned

work. It provides a number of library services to users, including general services, such as library information, book search and ratings, as well as personalised services, such as alerts, preferences, etc. The system also supports contents available in the library and in the Internet. The Neva has been installed in kiosks placed in the McLuhan Documentation Center at the University of Lubeck in Germany. Based on users' feedback, the author claims that the interface system is able to assist users in interacting with information systems and can be improved in terms of learning capability and new technology adoption. The author indicates that it is a new research domain for the application of human computer interaction in libraries and the concept can be expanded to other fields.

4.2 Automatic reference services

Some papers address the problem of using intelligent agents to provide automatic reference services to users. All of them apply reference agents in the virtual reference environment and are completed by researchers from Mexico.

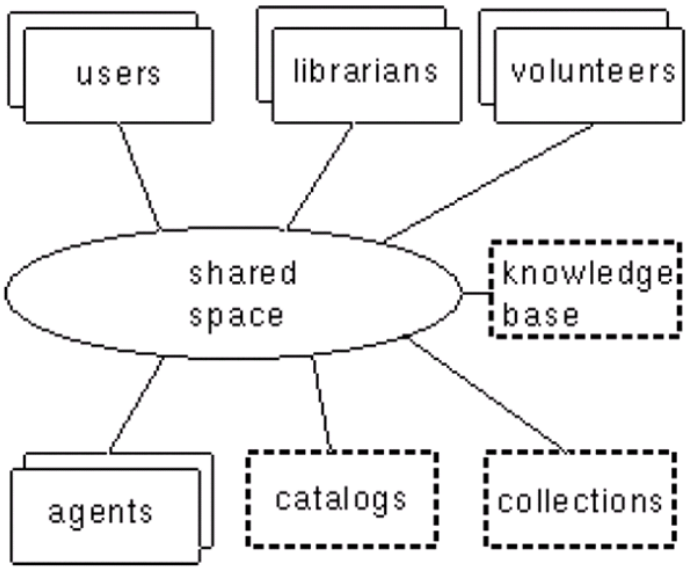
Medina and Sanchez (2002) refer to a number of studies, such as: (1) the Stanford Encyclopaedia of Philosophy project in which an expert team offers dynamic reference services (Zalta, 2001), (2) the Virtual Reference Desk in which reference agents delivering digital reference services (Lankes, 1999), and (3) the EDGES, an agent-based system supporting access to information from the repositories in the web (Rizzo et al., 1998). The master agents in the EDGES facilitate the communication between mobile agents and users. The EDGES agents are reference agents helping retrieve information

from different repositories. However, these projects consider information requests rather than the model for users and expertise.

Medina and Sanchez (2002) propose an approach incorporating reference agents into a virtual reference framework, the VRef environment. The extended VRef is illustrated in Figure 4.

Take in Figure 4

Figure 4. VRef's major components and participants (Medina, 2002, p. 33)



The framework supports the collaborative knowledgebase construction and the reuse of knowledge in a community. The reference agents are added to the extended framework and respond to users' queries automatically by comparing query terms with documents in the knowledgebase and any other resources connected to the system. The authors implement the extended framework in the VRef system. Based on the preliminary results from the system evaluation, the authors claim that reference agent is an alternative to human librarian to extend reference services. They indicate that future work includes continuing experiments on the system and applying new features to improve the

functionality of reference agents, such as context representation and reference support in the web.

Following the above work, Medina et al. (2003) experiment with the reference agents in the system using reference librarians and students. The system performance is evaluated by usability study methods. Based on the experiment results, the authors claim that the reference agents are successful in responding to many queries. Those 'nonsense' results generated by the system are caused by keyword ambiguity. The authors state that the extended VRef framework has many advantages, such as supporting knowledge reuse, eliminating result ambiguity and assisting users in a timely and collaborative way. They conclude that the reference agents are good alternative to human librarians providing reference services in DLs. The authors indicate that future work should investigate the use of ontologies to avoid keyword ambiguity.

4.3 Multi-agent architecture for library services

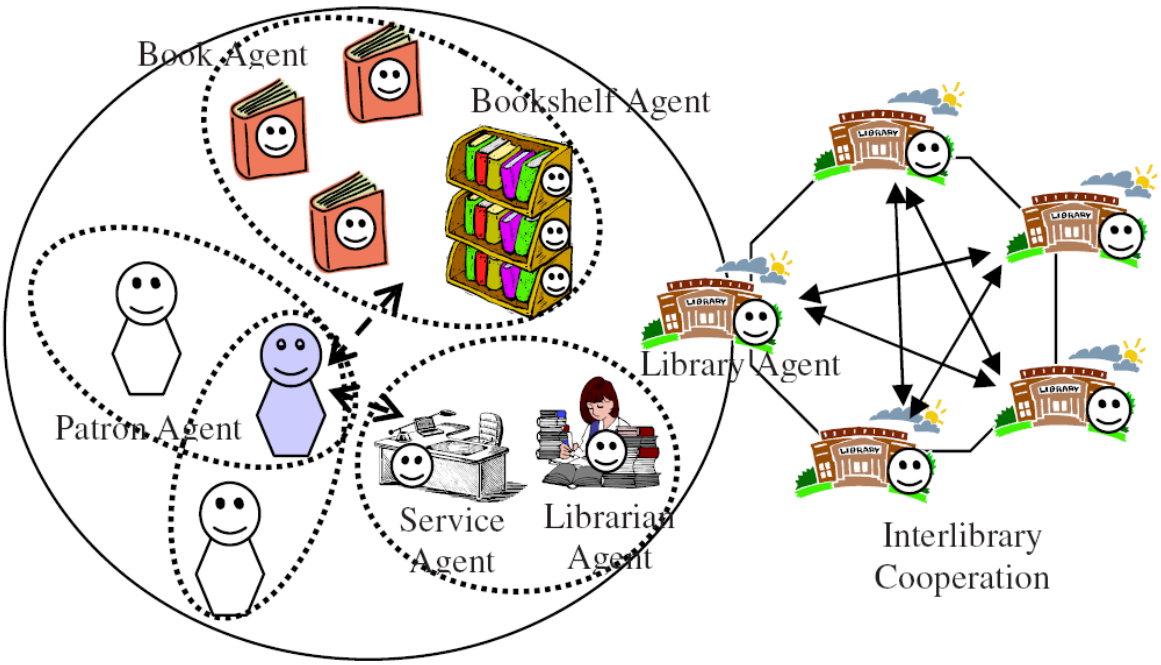
Minami (2005) in Japan appears to be the first to introduce the concept of modelling the entire library system as a multi-agent system. The author refers to the 'intelligent shelf' which is capable of reading books on the shelves (Minami, 2003). The problem is that the shelf itself cannot tell the specific location for a book. The author also refers to the intelligent browsing table in the AIREF Library which is able to collect information about users' reading habits. The information can be used in the arrangement of collections and shelves. However, the system does not have the features of recommendation and collaborative filtering.

Minami (2005) proposes a model of ubiquitous libraries (u-libraries) in which all objects, such as bookshelves, tables, and library collections, are viewed as agents. Radio-frequency Identification (RFID) tags, sensors and Reader/Writers are attached to these agents, thus the agents are able to collect data and communicate to each other. Through the analysis on the advantages and issues of the model, the author claims that the agent-based u-library model is helpful to libraries.

Minami (2008) expends the abovementioned model from a single library to include collaboration and co-operation among multiple libraries. The author proposes an agent-based model for entire library services. The paper presents three different types of models, including the concept model, the inter-agent communication method and the implementation method as illustrated in Figure 5 (Minami, 2008, p. 224).

Take in Figure 5

Figure 5. The concept model of library agent systems (Minami, 2008, p. 224)



The author claims that the concept model integrates participants, actions and services in a union framework. It is flexible and scalable to support collaborative services, such as inter-library loan services and collaborative online referencing. The paper indicates that future work includes the completion of the implementation and evaluation on the model as well as improving and refining the model.

5. Discussions and Conclusions

The majority of research in literature is about the use of intelligent agent technology in DLs. Because multi-agent systems support decentralisation of tasks and agent coordination, multi-agent architecture becomes a natural choice for DLs. Although tools have been developed in many projects, it's not easy for individual libraries to adopt these tools and other agent technologies. Much less research is on the utilisation of intelligent agents to provide or improve services in traditional libraries. The application of agent technology is still at the stage of research and experimentation and is far away from being widely adopted by libraries or library related projects.

A number of framework, concept models or architecture have been proposed for the adoption of intelligent agents in the library context, but only some of them have been implemented in practical environments. Adopting new architecture to a library needs fundamental changes to the library structure and systems and has both technical and social implications for the libraries and users (Dent, 2007). It might be more realistic to apply them in a brand new library rather than an existing one.

No doubt agent technology has benefits to libraries. However, the use of agent technology also presents challenges to libraries or librarians who want to be involved in

their adoption. The challenges include how to engage IT staff in the development process, how to educate users about the benefits of intelligent agents; how to make sure library professionals have the necessary skill sets to be able to participate in the design and implementation of the agent technology (Dent, 2007). Libraries need to consider carefully the benefits to users as well as the challenges they may encounter before applying the innovative technology. Currently it might be more suitable for publishers, system vendors and library consortia to adopt the technology to improve their database and system design in order to enhance users' experience.

The agent technology has great potential in many areas in the library context. Agents may be used to accomplish administrative tasks, or to improve library services, such as providing personal services and recommendations to facilitate users search information. It is possible to combine human-computer interaction technology to improve the interface design for library information systems. In literature, only the project Neva attempted to integrate the conversational agents into the system. There are many relevant projects in other fields, such as the virtual consultant, virtual secretary and virtual medical doctor. A virtual librarian may be an alternative to provide general or reference services to users.

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Acknowledgement

The author of this survey would like to thank Dr. Richard Frost at the University Of Windsor School Of Computer Science for his instruction on conducting a literature review and writing a survey in the field of Computer Science.