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A proposal to support ubiquitous libraries

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Abstract. Ubiquitous computing aims to make tasks that depend on computing transparent to the users, providing resources and services anytime and anywhere. This paper proposes a computational model to support ubiquitous libraries. The model provides appropriate information and tools to the librarian to maintain resources and services in a library, as well tools that allow offering better services to the library users. We developed a prototype that has been evaluated by thirteen volunteers in the Library of Centro Universitário Univates (Univates). The results showed a good acceptance of the model.

Keywords: Ubiquitous Computing, Mobile Computing, Ubiquitous Libraries, Intelligent Systems.

Introduction

Global organizations such as the United Nations (UN) and the World Bank are measuring the progress of countries in the Knowledge Economy area. The Knowledge Index (KI) and the Knowledge Economy Index (KEI) measures are universally recognized in this area. The KI measures the ability of a country to generate, adopt and diffuse knowledge. The KEI index examines if the environment is conducive to the effective use of knowledge in economic development (Sidek, 2010). Data for the year 2012 show that Brazil is in the sixtieth position of KEI and fifty-fifth in KI (World Bank, 2013).

The world is changing from an economy based on production to a knowledge-based economy, and any nation that has aspirations to play a significant role in this new economy must work on developing an innovative information system (Sidek, 2010). In this scenario, the ubiquitous availability of knowledge is strategic to the development of a nation and the libraries are relevant sources of knowledge.

Figures 1 and 2 present a survey, commissioned by the Online Computer Library Center (OCLC), that aimed to know how the use of libraries changed over three to five years preceding the survey, as well as how much each client believes that it will change over the next three to five years. At least 84% of respondents believe that their use remained stable or increased over the last years and 88% believe that the use of libraries will grow or at least be maintained the same in the following years (OCLC, 2006).

Historically libraries provide information services based on physical materials such as books and magazines. However, with the popularization of digital devices, libraries have demonstrated initiatives to update themselves to this reality (Minami, 2012). Moreover, in recent years, a large amount of information is becoming available through information technologies, so that modern libraries have embedded digital resources to their collections. Currently it is common for libraries to provide access to their collections through Online Public Access Catalogs (OPAC), digital libraries, databases, among others. However, in the library environment, collections of physical and digital documents are usually kept separate, so that users need to access different systems to perform any search (Veronikis, 2008).

The survey commissioned by OCLC also showed that the search engines were classified as "the first choice" for information retrieval by 72% of college students (Figure 3) (OCLC, 2006).

On the other hand, libraries are seen as more trustworthy and accurate sources of information than search engines, while search engines are classified as easiest to use, convenient and fast (Figure 4) (OCLC, 2006, 2011).

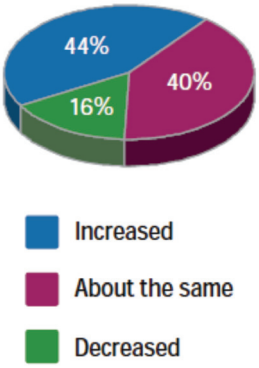


Figure 1. Past library use (OCLC, 2006).

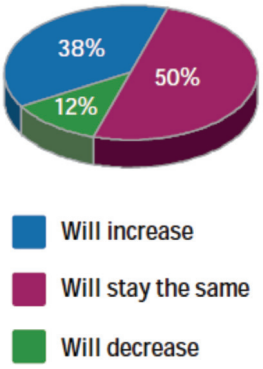


Figure 2. Anticipated library use (OCLC, 2006).

The American Marketing Association defines "brand image" as "the perception of a brand in people's minds. Brand image is what people believe about a brand in their thoughts, feelings and expectations". Around 75% of respondents reported that "Books" is the first thing that comes to their mind when they think of a library (Perceptions, 2011). Libraries have not been successful in leveraging their "brand image", even when incorporating increasing investments in electronic resources and web-based services. The renewal of the library brand depends on the reconstruction of the experience of using libraries (OCLC, 2006).

The nature of the library services is characterized by comprehensiveness, complexity and specialized information treatment, so that it is appropriate to provide a ubiquitous environment library (Huancheng and Miaolei, 2011). In a ubiquitous library it is expected that librarians can perceive easily the needs of library users, providing more appropriate and qualified responses.

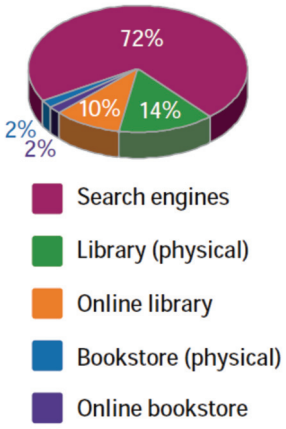


Figure 3. The first choice for information retrieval (OCLC, 2006).

The Ubiquitous Computing is an emerging area, made possible by the favorable conditions created by the growing advances in computing and communication technologies (Weiser, 1991; Satyanarayanan, 2001). On the other hand, from their earliest days, libraries have been associated with the creation and use of technologies for structuring metadata, interoperability, among others.

This paper presents a model for ubiquitous library support, called U-Library. The model provides support to library users and librarians. From user data activities provided by various library systems of a given library, as well as the contextual information provided by the U-Library Personal assistant, it becomes possible for the software agents to define user profiles and provide custom services and resources at any time and place. The U-Library stores users' trails, which are applied to define users' interest profiles. These profiles are used along with users' contexts (location, time and activity) in order to provide customized resources through user search and resources recommendation. Moreover, the U-Library model allows the integration of digital and physical resources by the use of interoperability metadata protocols.

Based on the study of related works, it is possible to indicate the following contributions: the support to librarians, the exploration of user activity records in the libraries systems (trails) (Silva *et al.*, 2010) and the use of content provided by external systems.

From the proposed model a prototype aiming an evaluation was developed. The prototype evaluation was carried out by thir-

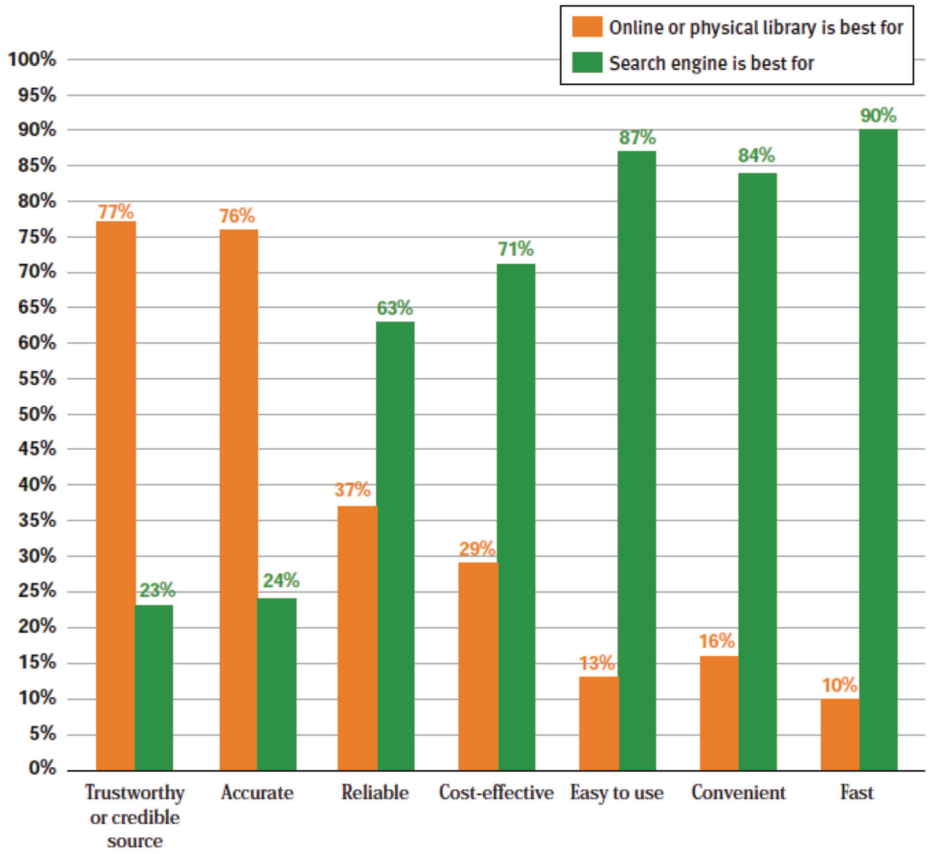


Figure 4. Characteristics of the main sources of information (OCLC, 2006).

teen volunteers in Univates Library, institution located in Lajeado, Rio Grande do Sul, Brazil.

This paper is structured into six sections. The next section describes and compares the related works. The third section proposes the U-Library model. The fourth section presents the implementation aspects and the following section approaches the evaluation aspects. Finally, the last section presents the conclusions.

Related works

This section presents works related with the proposed model, as well as a comparison that identifies the presence of relevant aspects for ubiquitous library environments: context awareness, dynamic profiles, library user support, librarian support, recommendation, use of trail, content and domain.

Guerra and Silva (2008) propose a model for ubiquitous environments based on semantic web services. The model is generic, but was validated through an implementation for the Mathematic Library of University of São Paulo (USP), aiming to provide a service to support library users in locating materials.

Son *et al.* (2008) propose the Library Interface Markup Language (LIML), aiming to provide digital library services with context awareness. The model uses a set of agents for communicating and processing requests.

Ching-Bang (2010) presents a ubiquitous learning environment based on navigation service in libraries environments, called Personalized Navigation and Ubiquitous Learning with Knowledge Agents for Intelligent Library (PNULKA). The model combines the RFID technologies, mobile agents and wireless networks.

Buchanan (2010) proposes a model that explores the coexistence of digital and physical documents, called Embedded Library (EMLI). The model supports the delivery of physical and digital resources, as well as the provision of services, given the user's context.

Hahn (2011) proposes a model for recommendation services based on the location of

Table 1. Related works comparison.

Model / Aspect	Guerra and Silva (2008)	Son *et al.* (2008)	Ching-Bang (2010)	Buchanan (2010)	Hahn (2011)
Context awareness	Yes	Yes	Yes	Yes	No
Dynamic profiles	Yes	No	Yes	No	No
Library user support	Yes	Yes	Yes	Yes	Yes
Librarian support	No	No	No	No	No
Recommendation	No	Yes	No	No	Yes
Use of trail	No	No	No	No	No
Content	Physical	Own digital	Physical	Physical / Own digital	Physical / Own digital
Domain	Generic	Library	Library / learning	Library	Library

mobile devices in library environments, allowing greater access to physical and digital resources.

Table 1 shows a comparison of the related works. Aspects were assumed to be present in each model when mentioned explicitly or when relevant evidences of their presence were detected.

With the exception of the *Hahn* model, which is based only in location, all the other models use context awareness.

Dynamic profile is the creation and maintenance of an automatic profile from information of user activities. Just *Guerra and Silva* and *Ching-Bang* explicitly mention the use of dynamic profiles. The first ones define the creation and update of a knowledge base from the user contextual information and the second one cites the use of a software agent for the analysis of basic user information in the recommendation process.

All proposed models are focused on the support of the library user, and none of them focuses on providing resources and services to the librarian.

The recommendation aspect is not supported by the models of Guerra and Silva, Ching-Bang and Buchanan. The Hahn model supports recommendation according to the user location in the library environment. The other models perform recommendation based on user profile or context.

Trails can be used to make inferences about the entities (Silva *et al.*, 2010). In the context of this work, the use of trails can assist in activities such as the maintenance of dynamic profiles and the inference of recommendations. None of the models explored this resource.

In relation to the content covered, this study identified three main types: physical (physical resource, such as a book), own digital (digital content repositories kept by the library itself), and third-party digital content (content maintained by third parties). The models of Guerra and Silva and Ching-Bang are restricted to physical content, while the Son *et al.* model contemplates only the own digital libraries. Buchanan and Hahn proposed the approach of physical and own digital content, however, only Buchanan presents a future concern, without solution, for support of digital content systems provided by third parties.

The model presented by Guerra and Silva, in relation to the domain aspect, is a generic model for service delivery, however, it was validated in a library environment. Ching-Bang mixed the library domain with the learning domain, since the model is integrated with learning environments. The other models focus specifically on the domain of libraries.

From the comparison between related works, it is possible to identify opportunities for contributions in ubiquitous libraries support. The aspects that deserve greater emphasis are librarian support, the use of trails and content types. None of the related works has librarian support. This support can result in a differential in the quality of services and resources available. The use of trails is noteworthy, since the traditional libraries systems store historic of use that can be converted into a trail base, allowing the construction of profiles and capturing relevant information to provide services by a library. Finally, the content types supported in related works are limited to manage systems by the libraries, while

the U-Library proposes a method that allows the use and availability of resources provided by systems managed by third parties.

U-Library

The U-Library architecture (Figure 5) has seven components, organized in three modules (Resources, Profiles and Trails), three software agents (Personal assistant, Interoperability and Recommendation) and a system for management and configuration (Administrative system). The following sections describe the model components.

Modules

The *Trails module* stores, manages and provides the trails. Trails consist of a sequence of contexts visited by an entity, storing information of resources and services that were used. These data are used to extract auxiliary information, relevant to the other modules and agents of the model.

To formalize trails in libraries, we propose the ontology shown in Figure 6, named *uloTrail*. The U-Library stores trails with the following information: system, activity, location, time, duration and entity. The *uloTrail* defines that library users, librarians and resources are entities that may be related to a particular context. This trail specification meets the definition of Dey (2001), who assigned four essential characteristics to the context (identity, location, activity or state and time).

The *Resources module* comprises a metadata database of physical and digital resources. This base is formed from the metadata synchronization with external systems, such as digital repositories, Integrated Library Systems (ILS), among others. The task of metadata synchronization is performed by the *Interoperability agent*. This module stores and provides resources to users through the *Personal assistant*.

Information retrieval systems aim to help users in the search for information. A traditional feature of information retrieval systems is that different users can send the same query. In this case, the system would return the same results list, regardless of the user. Personalized information retrieval (PIR) takes a step to better meet the specific information needs of each user, providing search results that are not relevant only to the query, but are also of particular relevance to the user who submitted the query (Ghorab *et al.*, 2013). In order to provide a personalized service, PIR systems maintain information about users and the history of their interactions with the system. This information is then used to adapt user queries or the results so that the information that is most relevant to users are retrieved and displayed.

The search engine of U-Library makes the customization of search results performed by the users, considering the degree of importance assigned in their profile for each term of interest and related to the degree of importance assigned to each metadata element present in the resource. In summary, the first results displayed in the search will be the resources that achieve the highest score. The score is composed by the weighted sum of the current metadata, multiplied by the weighting in the user profile for the same metadata having identical value.

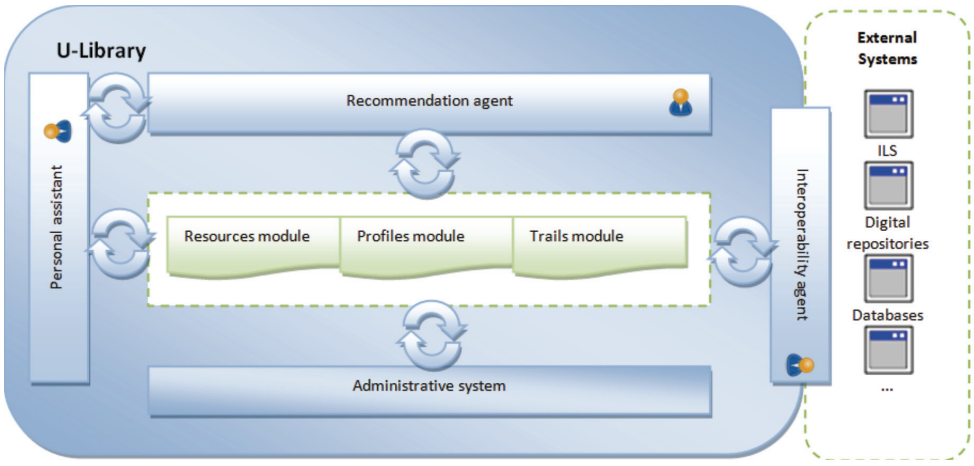


Figure 5. U-Library architecture.

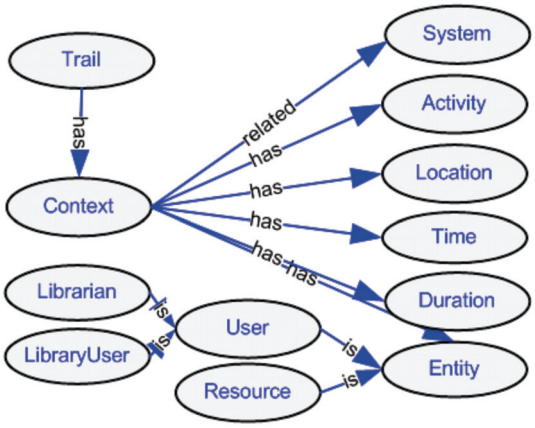


Figure 6. Trail ontology (*uloTrail*).

The *Profiles module* maintains updated the library users profiles, according to the context information and inferences made over trails related to their activities. This module is used to set preferences in relation to the delivery of services and resources. The U-Library defines a user profile ontology (Figure 7), called *uloLibraryUserProfile*. The ontology standardizes the information and enables interoperability with other systems. The ontology specifies a profile organized in three main categories: *Identification*, *ExternalIdentification* and *Interest*. The *Identification* category contains basic information about library user: code, password, name and email. The *ExternalIdentification* category stores one or more identifications relating a system to a login, allowing the library user to have a different identification for each library system. The *Interest* category stores information about the preferences of library users, identified from the analysis of their trails.

The update of the user profiles occurs in real time, after any update of contextual data related to users. Such data is collected and made available to the *Trails module* by the *Personal assistant* or informed by *External systems* and collected by the *Interoperability agent*. From the most recent trails related to a user, the *Profiles module* applies appropriate heuristics that can result in the update of users' interests.

Software agents

The U-Library is a Multi-Agent System (MAS) that has three software agents: *Personal assistant*, *Interoperability agent* and *Recommendation agent*. The i* framework was used for modeling the U-Library agents.

The i* framework consists of two modeling components to represent the intention of the actors. The Strategic Dependency Model (SD) describes the intentional relations of dependencies at process-level between actors. The Stra-

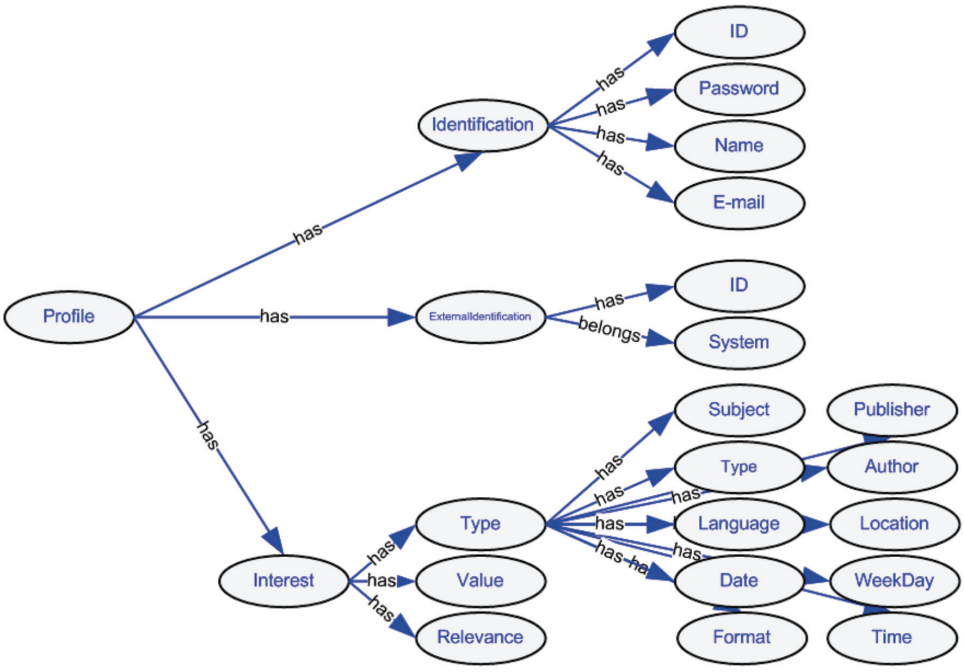


Figure 7. User profile ontology (*uloLibraryUserProfile*).

tegic Rationale Model (SR) is used to describe and support the decisions of each actor (Yu, 1995). The SR model contains the specification of tasks that each agent needs to achieve the goals of their relation of dependencies. Figures 8 and 9 show both models to U-Library agents.

The *Personal assistant* is an agent that follows the users on their device. This agent is responsible for the communication between the user device with other agents and modules of the system. It captures and provides contextual information from the user, as well as

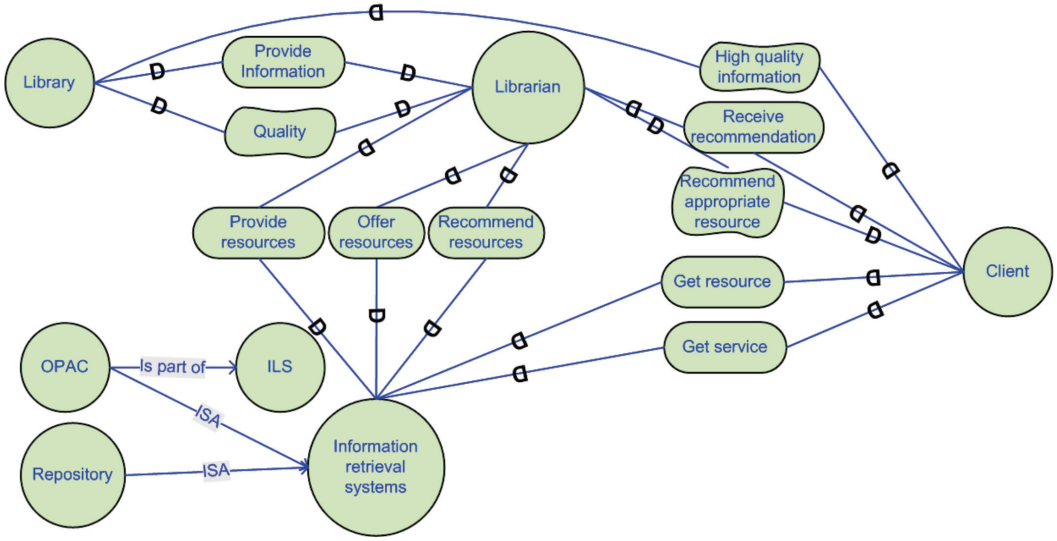


Figure 8. U-Library Strategic Dependency Model.

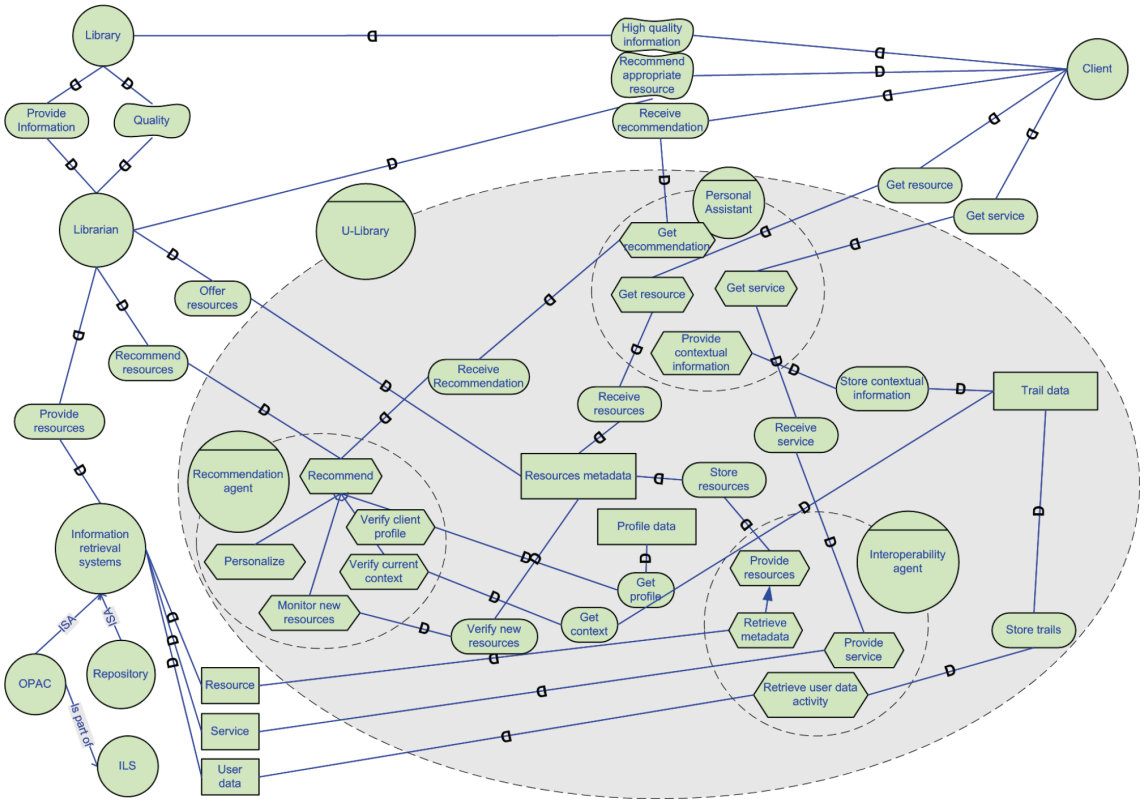


Figure 9. U-Library Strategic Rationale Model.

provides resources, services and information from agents and modules.

The *Interoperability agent* supports the U-Library interoperability with other systems that are part of the library environment, such as ILSs, information databases, digital libraries, among others. This agent performs the recovery and the synchronization of metadata resources provided by external systems, storing them in the *Resources module*. The metadata retrieval from external systems occurs through the use of traditional interoperability protocols of libraries, such as: Open Archive Initiative Protocol of Metadata Harvesting (OAI-PMH), Search/Retrieve Web Service (SRW), Search/Retrieve URL (SRU) and Z39.50. In addition to the resource metadata, the *Interoperability agent* retrieves data of the activities performed by users in external systems, such as loans, reserves, renewals, downloads and views. The information is obtained through specific web services and recorded as user trails.

Hahn (2011) mentions that recommendation is a critical component to search for information. Moreover, librarians traditionally recommend items based on the needs of library users. Thus, the *Recommendation agent* monitors the library users through their trails, monitors new resources obtained by the *Interoperability agent* and identifies opportunities of deliver recommendations tailored to the user's interests.

In order to provide recommendation to the users and personalization of search results, the U-Library model proposes the use of content-based filtering as a recommendation approach. Content-based filtering is most adequate to the recommendation of textual items, since resources are usually described by keywords (Salton and McGill, 1983). In addition to content-based filtering, heuristics are used to assess contextual aspects in order to provide a ubiquitous user experience.

Implementation aspects

This section presents the prototype of the U-Library. The implementation of the modules was performed using the Java language. The communication with the *Personal assistant* was developed using the REpresentational State Tranfer (REST) technology, through the use of the Restlet library (Restlet, 2013).

The ontologies were used as the basis for developing a class diagram, which was mapped to a structure of a relational database. The management system database used was the PostgreSQL.

The software agents were implemented as threads in Java. A logical implementation of the agents was made based on rules in the form of simple reactive systems. These agents select their actions based on their current perception of the environment, in other words, according to the context, interests and information about resources and services, the agents must act appropriately (Russel *et al.*, 2004).

The *Personal assistant* was developed and tested on Android mobile Samsung Galaxy Tab 2 GT-P3110. The *Personal assistant* also makes use of Restlet library for REST communication with U-Library modules. The *Interoperability agent* was partially implemented, allowing synchronization of metadata resources with OAI-PMH protocol (OAI-PMH, 2013).

The *Recommendation agent* performs content recommendation through the similarities between resources and subjects of user interests. The similarity was implemented using the similarity function of the PostgreSQL *pg_trgm* module (PostgreSQL, 2013).

Figure 10a shows a screen of the *Personal assistant* which allows consulting the interests of library users, getting the key subjects and their respective relevance. The availability of this information allows the librarian to guide library users in a personalized way.

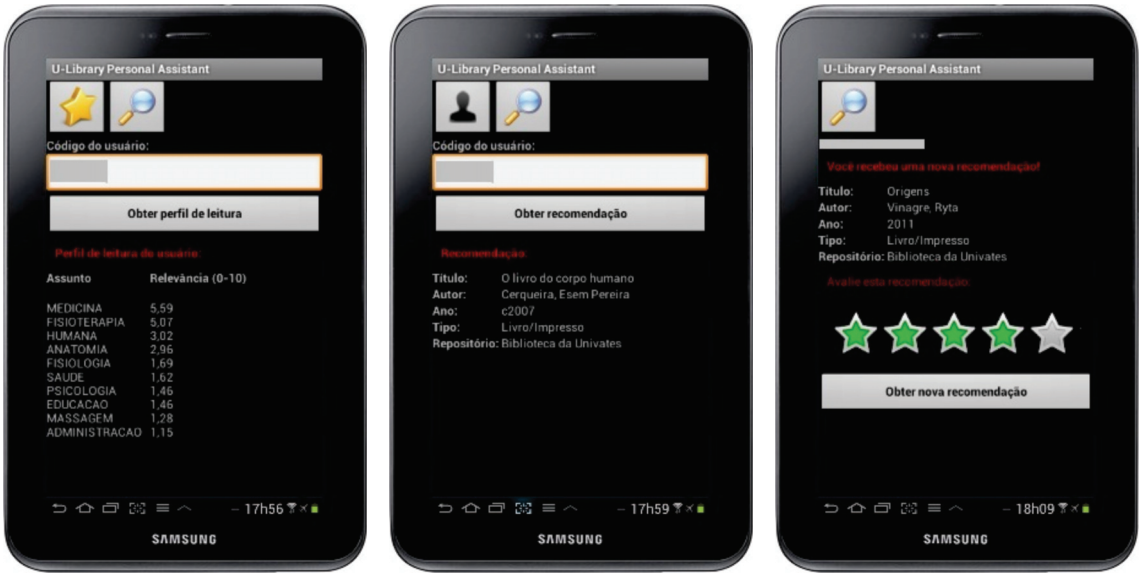
The screen shown in Figure 10b allows to get recommendations based on the library user profile, allowing the librarian to perform relevant indications of new resources.

In turn, the library users can get recommendations according to their profiles, as shown in Figure 10c.

Evaluation aspects

This paper presents an experiment that was oriented to the usability evaluation of the U-Library, in support of library staff. The experiment involved thirteen volunteers, among them two librarians and eleven attendants of Univates Library. The experiment was conducted in the library environment, simulating attendances to library users with U-Library support.

With the purpose of assessing the U-Library model, its database was populated with real data from the Univates library systems. The information on users' activities was converted and stored in the format of trails in order to serve as a basis for defining the library user profiles.



(a) User profile (b) Librarian recommendation (c) Resource recommendation

Figure 10. Personal Assistant.

The volunteers answered a questionnaire containing statements related to the experience in using the U-Library prototype. Responses were standardized according to the Likert scale (Likert, 1932) of five points: Strongly disagree (1), Partially disagree (2), Indifferent (3), Partially agree (4) and Strongly agree (5). The questionnaire items were developed based on the concepts of the technology acceptance model (TAM) proposed by Davis (1989) and applied and expanded by Yoon and Kim (2007) in their study on the acceptance of wireless networks.

The TAM model considers the following aspects as major influences on the acceptance of a new technology: the degree to which people believe that the technology could decrease their efforts (ease of use) and the degree to which people believe that the technology could improve performance in the development of their activities (usefulness perception).

The following statements were used to evaluate the ease of use perception:

- The U-Library Personal Assistant is easy to understand;
- The U-Library Personal Assistant is easy to use;
- In the U-Library Personal Assistant, the information is presented clearly and objectively.

Figure 11 summarizes the results, showing that 69% of volunteers strongly agree and 23% partially agree with the statements related to ease of use. Only 8% of volunteers have positioned themselves as indifferent to the statements.

The following statements were applied to evaluate the usefulness perception of the U-Library:

- The presented recommendations were relevant to the library users;
- The use of the U-Library facilitates the library user support activity;
- The U-Library should be used on a day-to-day basis.

Figure 12 shows the summary of results of usefulness perception. In this case, 61% of volunteers strongly agree that the model would be useful in their routine and that they would improve their performance in the development of professional activities in a library. Furthermore, 31% partially agreed and only 8% showed indifference to the model.

In summary, most of the volunteers strongly agreed that the U-Library is easy to use and useful. None of the volunteers disagreed with the statements, demonstrating a good acceptance of the U-Library.

Conclusion

The study presented in the second section showed that none of the related works meets all aspects evaluated in this paper. The U-Library presents as differentials the support to

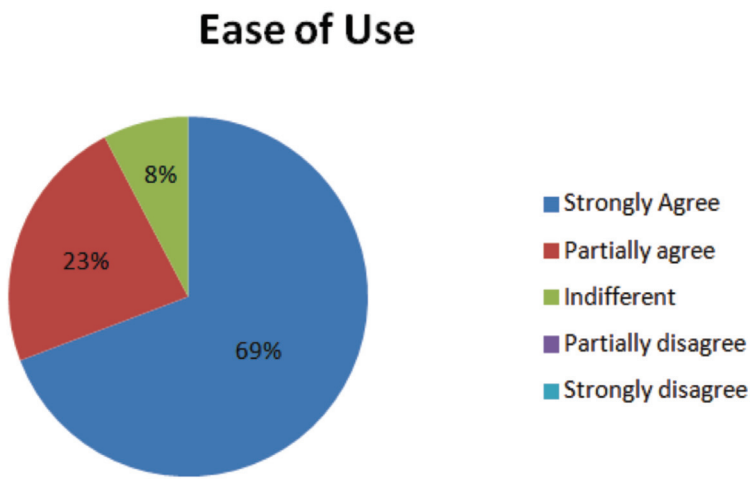


Figure 11. Ease of use graph.

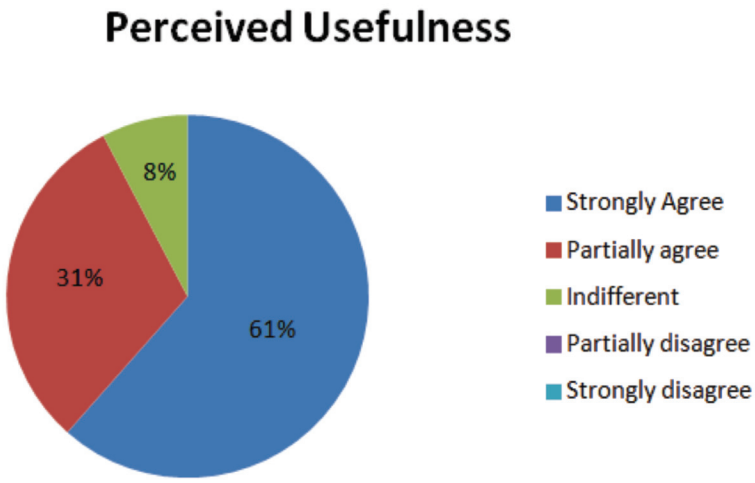


Figure 12. Usefulness perception graph.

the librarian, the use of trails and the support to resources managed by the library in combination with those provided by third parties.

The use of trails has relevance, since many libraries systems have databases with the history of services provided, so that this information can be converted into a base of trails, allowing the construction of profiles and capturing relevant information to the services provided by a library. The support to content types grows in importance to the point that the goal is to enable the provision of resources that are held by third parties, namely, resource databases signed by the library or made available to it.

The U-Library model consists of an initial proposal, as the prototype is a partial implementation. However, we observed good acceptance and interest of users. As future works we intend to perform the full implementation of the U-Library, as well as to perform evaluations with a greater number of users. We also intend to deploy the U-Library in the UNIVATES Library and in the Library of the Universidade do Vale do Rio dos Sinos (Unisinos).

Acknowledgments

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