Evaluation of User Interaction in Digital Libraries

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Abstract. Digital library interaction evaluation has, by nature, a user centered perspective, which directs the scientific research to the benefit of the user and narrows the research parameters. In this paper we propose a new framework for the evaluation of interaction and we introduce the concepts of usefulness, usability and performance as the main contributing factors for the creation of a rational and successful interaction. The framework attempts to trace and highlight some of the interaction evaluation requirements and parameters, in order to be sufficient in many different contexts.

1. Introduction

Digital libraries have been introduced to the daily life of a significant part of the scientific, educational and research population. These systems have left the narrow walls of the laboratory environment and address the real needs of users. The usage monitoring of these systems provide useful information for their evaluation and improvement processes. However there is a plethora of inter-dependent factors influencing the overall user interaction with a digital library and therefore there is a vital need for a holistic approach in evaluation, which should consider every aspect (agent, attribute, level etc) that may affect the interaction process.

Digital library interaction shares experiences from two distinct communities, the Human Computer Interaction (HCI) and the information science community. The HCI community is carrying the expertise on the improvement of user interaction with a new information management medium, while the information science community adds the scent of domain knowledge in the sense of information behaviour. This conjunction imposes the investigation of the iterative exchange of dialogue elements between the user and a digital library system, which are translated through an interface and aims to fulfill the user informational needs.

Digital library evaluation has many facets depending on the characteristics and the perspective of the evaluating agent. Borgman states that *"the methods and metrics for evaluating digital libraries will vary by whether they are viewed as institutions, as information systems, as new technologies, or as new services"* [1]. Moreover each developer, evaluator or project partner applies his own expertise over the evaluation domain and concentrate on the most important issues according to this expertise [2].

This has lead to the expansion of digital library evaluation to sectors like database structure, network architecture, protocols interoperability, development of intelligent and adaptive technologies, performance of retrieval algorithms, collection development, digitization policy assessment, usability, information architecture, interaction design, information behaviour and many other.

Digital library interaction evaluation aims to the user benefit and focuses mainly on analyzing his behavior when he interacts with a digital library. The main factors affecting user behavior are the system performance and the content appropriateness to the user needs. The notion of usability isn't able to cover those aspects, as the heterogeneity of the attributes (collections, technologies, users) is growing equally to the spreading of digital libraries.

This work aims to discuss the issue of digital library interaction evaluation, which is still a largely unexplored area. The present paper is structured in the following way. We begin with the periphery of the model describing the interaction components and their attributes. This description constitutes a basis on which the evaluation elements (methods, criteria etc.) will be developed. Then we move towards the center of the model and we discuss the concepts of performance, usability and usefulness that are derived from these components. Finally we move into the core of the model, where we outline the requirements of an evaluation framework of the user interaction in the digital library. These requirements will be taken in consideration at the selection of the appropriate methods for evaluating the interaction.

2. Description of the Interaction

The proposed model aims to describe the digital library interaction process and to provide a basis on which the interaction evaluation elements (methods, criteria etc) will be developed. It has similarities with other descriptive schemes [3], especially in the definition of the participating components: user, content and system. However, our model explores and emphasizes the dialogue elements that are expressed and transacted during an interaction period. Moreover our model recognizes the iterative nature of the interaction events. The predominant interaction process in complex information systems, like digital libraries, is full of revisions, filtering and judgmental actions that cannot be represented in idealistic "one-off", linear interactions. As noted by Toms *"the user may recycle in multiple, nonlinear ways, through category selection, cues, and extraction"* [4]. Linear kind of interactions are in accordance with more unstructured means of information management, like search engines, where the nature of the tasks encourages simplified interface structures and items' representations and leads to limited use of advanced features, indicating user's lack of information literacy and awareness [5].

2.1. Components of the Interaction

The main components of the interaction process are three; the user, the content and the system. One can argue about the abridgement of content and system in a wider component. For example Saracevic [6] considers the participant "system" as an ample

frame where different levels exist, among them the “content level”. However the nature of the content and especially the structured organization, architecture and presentation of information, impose the content as the differentiating factor between digital libraries and other systems attempting to tame information overload, like search engines, and are characterized by simpler information architectures. Furthermore the content manipulation requires different skills migrated from other contexts and paradigms. For example the user may reproduce behaviors from the usage of printed media and re-project them on his digital media usage models. Despite of the medium, the concept of content usefulness (or utility, topical relevance etc) and the user cognitive perceptions on this concept are formulated by multiple factors. At this micro-level of research we prefer to concentrate on the three components and the interactions between them. Previous research efforts on evaluation of digital libraries support the selection of this triptych [7].

Figure 1 presents the three interaction components and their relations establishing a framework for digital library interaction evaluation. Each of the components has a set of properties that are expressed during the interaction as needs, requests and responses. The analysis of these three interaction components illustrates the features of each one and the elements that import into the interaction procedure. Moreover the model allows to evaluate the relationships between the three components, since the background relationships, those behind the interface, that take place between the “system” and the “content” are projected and judged by the user. Thus this model, except from describing the interaction of user with the digital library, represents the interactions between the components of the digital library itself.

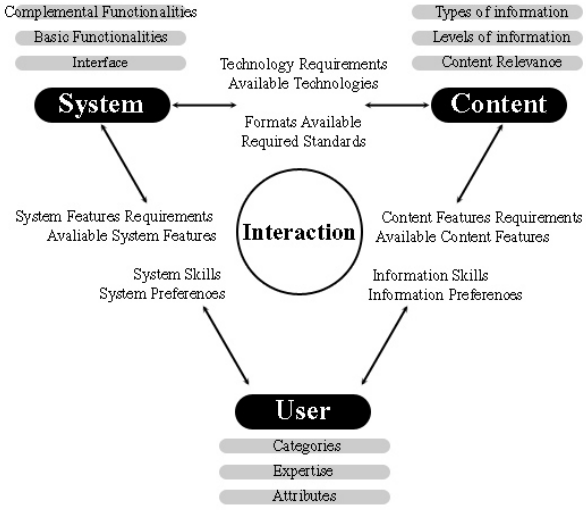

Figure 1: The Digital Library Interaction Components

a. User

The user is the first pole of the interaction process and his characteristics are complex and constantly evolving. Therefore interaction modeling and evaluation is a difficult task. The digital medium has magnified this aspect, since the user has even more blurred characteristics. The collapse of spatial and temporal barriers has made the extraction of sound user information arduous. Even in more specific evaluation projects, where research parameters are constrained, the number and the attributes of the users are numerous and complicated [8].

The digital library user is a debatable entity, as except the end user of a digital library, there is also the developer of the system (librarian, computer scientist etc). This distinction is necessary since in modern digital library systems these roles may overlap, and the end user may participate in the development of a digital library collection. However the end user's involvement with a digital library is dictated by a higher need that feeds his information seeking process, while the user-developer has as a primary need the completion of a set of tasks. The context of the information need that pushes the user to visit a digital library is a crucial attribute of the interaction, as it recalls previous user experiences and applies cost/benefit matrices [9].

Apart from this short categorization other user attributes emerge. One of these is the expertise of the user, both on system use and information exploitation. It is commonly hypothesized and confirmed that novice users have not the necessary skills for the control of both the system functionalities and content characteristics. However novice young users of a system, that acquire more computer operation knowledge tend to present better performance indicators, instead of older novice users [10]. User instruction and support significance has been underlined early enough for the incremental development of a reasonable digital library interaction [11].

b. Content

Content is the prime reason for interacting with a digital library. This component addresses the user's information needs resolution. The relation that maintains with the user is strongly depended on a higher level need, an informational one. The appropriateness of content to the initial need is engaging, so the perceived usefulness of content is the first selection criterion for the user. The various shifts encountered on the initial need and the weight changes of the perceived usefulness are forcing the user to reform his information needs and to re-direct his information strategy (if any).

Other attributes arise from the nature of the content, for example the level of information, the type of resource etc. Digital libraries host and administrate a number of type of resources, where in parallel are constructing and managing surrogating formats for the discovery and the retrieval of these resources.

c. System

The system is the most well known component of the interaction process, as it is governed by the rationale of the developer. It consists of various subsystems that perform different operations. The interface is the first one, a visual controlling panel, which affects the interaction in terms of information architecture, interface structure, aesthetic comfort, satisfaction and appropriateness. The most important subsystem, by

far, is the IR mechanisms, the basic functionalities that permit the user to interact with the system and retrieve the desired information. The evaluation of IR mechanisms are under the stable terms of precision, recall, relevance and response time, which all of them are influencing the interaction process not only on a completion stage, but also on a stage of satisfaction. A third subsystem is the set of supplemental functionalities, such as peripheral services. In modern digital library systems we proliferate such advanced functionalities that permit the user to elaborate content types, e.g. to carry out certain information pieces, and to cooperate with system features, e.g. to automate a part of the monitoring procedure, or with a human agent, e.g. to ask for reference. The "thin red line" that separates the basic from the supplemental features of the system is a debatable issue, especially between the computer and the library/information sciences.

2.2. Relationships Between the Components

Many research approaches consider environment as a crucial factor in the digital library development and evaluation, which affects the information seeking process [12]. In particular the user's environment is acknowledged as a contributing factor in several stages of information seeking, like Forster's "opening" stage [13] or Ellis and Haugan's "distinguishing" stage [14]. In accordance to these approaches we consider that environment plays a significant role to the interaction influencing each of the aforementioned components. For example, the social aspect of digital libraries is of nodal importance, since it influences the user information seeking behavior, but same considerations apply to the other two components. Both the system and content are co-existing objects into vast systems, called "ecologies", that affect their state and their particular role in interaction. An ecology example is that the content of a digital library may be (more or less) topically relevant with the content of another collection and the technological options may make their interlinking feasible. However, possible access restrictions may deter the user and prevent him from using it. Thus, the conjunction of these sub-environments forms a diverse environment that influences the user interaction. Moreover, many digital libraries tend to be supported by physical organizations (libraries, archives, museums), forming hybrid spaces, which integrate the physical and the digital dimension. The way and the scale of integration depend on the environmental framework constituted by the structure and operation of the physical organizations.

User expresses his skills and preferences during interaction. User skills help him to understand the typology of the content resources, their relevance to his informational needs, and contribute to the formation of an information strategy. Furthermore these skills help the user to control the system interface, to understand the system features and to utilize the system functionalities to perform his actions. The user skills are closely related with the system and content attributes. This means that the user has to adapt to certain system features and to develop specific skills in order to utilize and manipulate the system functionalities and components, independently on the grade of the system adaptation to the user profiles.

On the other hand user preferences affect the way of expressing his information needs, utilizing the system features and in general his information seeking behavior.

The preferences, as an objective of user studies, emerge from usage patterns and enlighten the developers about the activities for system development/maintenance [15], or content enrichment [16].

Many user and usability studies conclude with a list of system or content requirements that the user would like to see as features of a digital library or in a collection of electronic resources [17, 18] and may or not be fulfilled. Although many commonalities exist among the various systems and standardized formats of information are available, there are still many differences between the system and the content of each digital library. This variety in system features and content types demands from the users to behave in a different manner and therefore the digital libraries develop various instruction programs or usage guides. Information literate users may have acquired these skills, either in a structured and methodic way, provided by an authorized organization or the digital library itself, either in an unstructured and anarchic personal way.

In any case user's information needs direct his skills to respond to system feature classes or content typology. For example the user's information need may entail the request and exploitation of surrogating formats of information, even when the corpus of the resource is available. The transformation of this information need to interaction depends on the multiple aspects that an interactive session and its tasks may have. Hansen groups tasks into four main types, namely work task, search task, system task design and interaction task, which are affecting the overall interaction [19]. Hansen highlights the significance of "task performance process", as a means to understand the information retrieval interaction and wider framework of monitoring and assessing the information seeking process.

3. Interaction Attributes

A next step is to trace and define exactly the desired characteristics of interaction in the digital library environment. This objective can help the developers to set the primary standards that the digital library should achieve and to guide the definition of more stable and user based evaluation criteria. Broad categories of criteria can be analyzed into subcategories covering every possible interaction aspect. In this section we enumerate some interaction properties that are subject to the evaluation process and cover all the space in the triangle of Figure 1.

3.1. Control

The user control over the interaction is extremely important. Sometimes the control outmatches the perceived efficiency or the easiness of a system usage [20]. Park's study high-lightened the fact that over-simplified interfaces, which attempt to address many retrieval variables, will not conclude to high estimation and appreciation on behalf of the user and that the user is eager to sacrifice efficiency, convenience and easiness of use (this means valuable time and work) for the sake of control. Control is the factor that decreases user's uncertainty and lessens the risks of frustration. Sub-properties like consistency, navigational aids, error restriction, familiarization and

user awareness should aim at the maximization of user's abilities to control the interaction with a digital library system. For example the knowledge of user about resource additions or changes in access status could help him to access the content in a more effective and efficient way.

3.2. Shift management

One significant interaction property is the shifts that emerge during an interaction. Shifts are the changes encountered in the user behavior and are caused by some, distracting in most cases, factors that appear both in content and in the system. Xie [21] investigated the concept of shifts during an interactive information retrieval process and concluded on the extraction of four types of shifts, the planned, alternative, opportunistic and assisted. These shift types represent alternations on the user's strategy, intended or unintended, stimulated by informational marks. Those marks may be originated by system or human interference, either as static supporting functionalities, e.g. a list of search tips or a textual guide for the improvement of search strategy or as more dynamic, like those originated by intermediated modes of collaboration.

Similarly visual or technical stimuli may force the user to change his route. The issue of navigation is one of the most common problems in the field of usability testing and problem detection. Poor navigational support by the interface is caused by poor information organization and structure, especially in large scale digital libraries. Bryann-Kinns, Blandford and Thimbleby [22] focus on the troublesome nature of interaction events and provide a categorization. They illustrate that the user may face a blind alley, an interactive trap or an interactive detour. In all these categories there is an unwilling change in the route of the user that may force him to abandon his interaction with the system. According to [22] these changes may be caused unintentionally, where the factors of mistakes, slips, cognitive inappropriateness, play their role.

The shifts address also the notion of serendipitous information retrieval. Serendipity, as the unstructured and unplanned location of interesting pieces of information, is an expression of user's instable and ill-defined information need. The shifts are indissoluble bound with the next property of interaction, lucidity, as part of the problems is caused by the blurred image of the user about the system. Ideal shift management should demand better designed support functionalities and feedback mechanisms.

3.3. Lucidity

According to Bryann-Kinns, Blandford and Thimbleby point out lucidity helps interaction to proceed *"in a sane, rational, and easy to understand way with respect to agents objectives and constraints, and their understanding of the interactive possibilities of the system"* [22]. Lucidity, as an interpretation of visibility is a vital property of a usable interface. Closely related is the concept of affordances, a property of interaction design domain, where the purpose of each object, visual or/and textual

(mainly) in the digital library, should be apparent and understandable. For example boxes of item selection in a results refinement process should be visible in order to identify their operation. The concept of affordances governs our physical world and accost to the perceptual models that the users immediately form each time is met with something unfamiliar. Thus, the elements in a digital library, apart from being visually luculent, must also enable the activation of the concept of affordance. Thus lucidity can be achieved by visual and semantic identification of system and content features, understandable terminology, visual comfort, etc.

4. Requirements for the evaluation

The main questions defining the main issues before and after evaluation are “who, what, where, when” and “how”. Figure 2 presents the three broad categories of evaluation criteria, placed on the interaction triangle, while Table 1 presents these criteria in a more analytic, but in none case thorough, way. Each one of these broad categories of criteria corresponds to each side of the triangle, where attributes of each component are interchanged.

Particularly we concentrate on the two sides of the triangle, namely usability and usefulness. This approach is contextual with the Technology Acceptance Model (TAM), which is used for tracking the perceived quality of information systems and their acceptance. TAM has been used in many system cases, like digital libraries [23] or portals [24]. Additionally the third side concerning performance evaluation meets the rich work done by information retrieval evaluation and it is out of the scope of this paper, which focuses mainly on the interaction evaluation.

Usability defines the quality of interaction between the user and the system. It helps the user to manipulate effectively a system, in an efficient and enjoyable way and to exploit all the available functionalities. A usable system is easy to learn, flexible and adaptive to user preferences and skills.

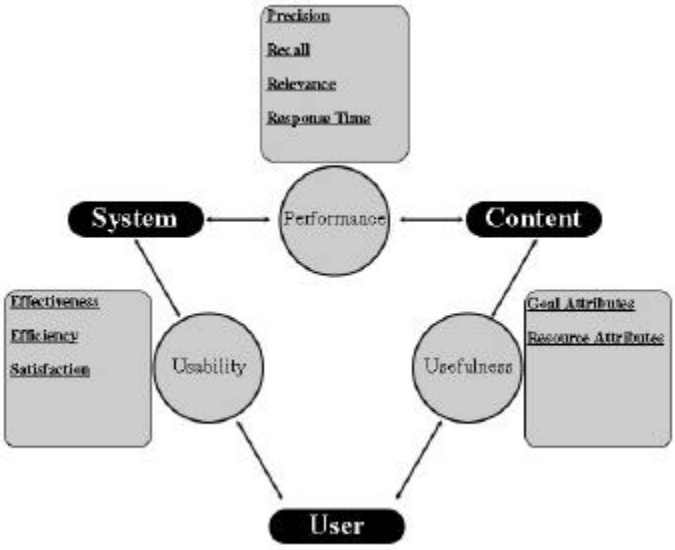

Fig. 2. Categories of Evaluation Criteria of Digital Library Interaction

The second category of criteria concerns the user and content components. The content usefulness and relevance to the user tasks and needs are the reasons behind the selection and usage of a digital library. This relevance is translated into actual relevance, type and level of resource relevance [25] and task relevance.

Table 1. Categories of Evaluation Criteria

Category	Criterion	Sub-criterion	Metric
Usability	Effectiveness *How effective can the user be?*	User performance	Number of accomplished tasks, number of abandoned tasks, number of serendipitous accomplishment of tasks.
		Error generation	Number of errors generated, types of errors, cause of errors, severity of errors, recovery time.
	Efficiency *How efficiently the user can accomplish his tasks?*	Completion time	Completion time per task, number of accomplished in a certain session, use of support functionalities, e.g. FAQs.

		Learnability	Number of questions, types of questions according to task.
		Task completion context	Time available, resources available, e.g. user accessibility to the DL.
	Satisfaction *Does the interface and the IR mechanisms are satisfying the user*?	Aesthetic comfort	Aesthetic appropriateness, visual and textual consistency, visibility of interface.
		Readability	Opinions about writing style, clearness of texts, fonts contrast.
Usefulness	Goal attributes *What attributes has the information need that affects the information retrieval and use?*	Relevance	Topical relevance, commitment with the quality of information.
		Utility	Importance of the task to the information need, consequences of non accomplishment
		Complexity	Number of sub-tasks, order of execution, dictation of specific resources.
	Resource attributes *Do the resources acquire attributes that attach to the information need? Do these attributes have qualitative characteristics?*	Currency	User judgments of the timeliness of the resource, suitability with the task.
		Level of information	Number of available level choices, e.g. surrogating formats, number of chosen levels.
		Reliability	User judgments about the reliability of the authoring/publishing/ recommending agent.
		Format	User judgments about the format and the suitability to the task.
Performance (Criteria are here indicatively stated)	Precision		Division of the number of relevant documents by the number of those retrieved.
	Recall		Division of the number of relevant documents

	retrieved by the number of relevant documents.
Relevance	Similarity between the query term(s) and the documents.
Response time	Time needed to perform a query and to present the results to the user.

There seems to be a correlation between the objective or subjective methods of data collection and analysis, and the quantitative or qualitative nature of these data. Automated data collection methods, like transaction log files, tend to produce quantitative data, which are useful to describe the interaction state. Methods based on the users opinion are likely to produce qualitative data, which may interpret and explain the actions of the user. Both kind of methods should be used in conjunction to formulate an image of the actual usefulness of the content and the usability of the DL, otherwise the image may be incomplete.

An issue concerning the realization of interaction evaluation is the personnel participation. Usually the developers evaluate the performance of a system. In our case computer scientists and librarians apply specific criteria and create their own view about the digital library operation. In the case of usefulness and usability, users are more active entities participating in surveys, questionnaires as well as in experiments for the monitoring of their behavior, under simulated or real conditions. The participation of users in the evaluation process is welcomed, but in order to lead to more firm results, it has to be combined with the opinion and the insight that a developer can offer, even in user centered methods of evaluation [26].

In order to evaluate digital libraries problems also emerge from the dispersed allocation of user population. This fact limits the applicability of subjective methods for data collection, like user observation in a controlled environment, e.g. a laboratory or even in their work context. Online questionnaires and surveys are the most commonly used subjective methods for the collection of data in the case of remote users, especially in the case of large sample population. Questionnaires and interviews are also the main means to collect the perceived usefulness of content to specific classes of users.

Usability can also employ the knowledge and experience of HCI experts, like in the case of heuristic evaluation or formal usability evaluation. Usability laboratories is the most common place for usability testing, although certain methods suggest testing in the real environment, where the users feel more comfortable and the extraction of more meaningful and representative data is easier. Recent developments in technology allow the setting of mobile laboratories in the real environment of the user, enabling the objective recording of user interaction. However the “where” question is attached not only to technology, but manly to the costs for purchasing and administrating the technology, as well as to the surveillance of the real user behavior.

Evaluation can be summative or formative, meaning that it can take place in various stages of the development and the release of a digital library system. Certain methods correspond to a certain type of evaluation. For example comparative analysis is preferable to be undertaken after the release of a digital library, while heuristic evaluation or usability testing of prototypes can be undertaken during its

development. Other methods e.g. user studies can precede the development to inform the developers about the characteristics of the user community. They ate not directly relevant to the evaluation of the digital library, but they are a useful development stage for risk minimization and user centered design assurance. Nevertheless evaluation should be done in iterative way to ensure the following of changes of user's profile and developments in system technology.

Table 2 presents synoptically, how someone can answer the "how to evaluate" question. The "how" question is indispensable with the rest of the requirements questions, as it is depended on the conditions under which evaluation will take place. In the table we relate the methods with the criteria presented in table 1.

Table 2. Relation Between Criteria and Methods

Method(s)	Description	Outcome	Criterion
Comparative analysis	Collection, comparison and analysis of the available features found in system and content in same or similar information systems.	Detection of best practices, and desired and undesired examples.	Resources attributes (currency, level, format etc). Usability (user performance, error generation, in regard to navigation, consistency etc.).
User studies	Collection of descriptive data through surveys and questionnaires.	Formation of a user profile, especially on demographic data, i.e. skills and preferences.	User attributes (age, sex, role, skills, preferences).
Transaction log analysis	Collection of descriptive data through recording and meaningful interpretation of the user interaction routes.	Detection of use patterns and regularities (what, how long, when, in what order, what connections between selections etc).	User attributes (activity). Usability (effectiveness, e.g. performance, error generation, efficiency, e.g. completion time, completion context).
User scenarios/ Cognitive walkthroughs	Observation of user behaviour to system and content use. Small samples of users are required to represented communities of the same class.	Attempt to gain an insight into the cognitive models of the user regarding information behaviour and potential use, and ways of system usage.	Goal attributes. User effectiveness. User efficiency.
Questionnaires and surveys	Collection of opinions and reviews about the digital library features.	Measurement of user satisfaction with the overall system and/or content.	Goal attributes. Resource attributes. User satisfaction.

Personal interviews and focus groups	Collection of data through opinions and reviews. Also through interpretation of user behaviour during the process.	Measurement of user satisfaction with the overall system and/or content.	Goal attributes. Resource attributes. User satisfaction.
Expert participation methods ▪ heuristic evaluation ▪ formal usability testing ▪ standards compatibility check	Invitation of domain and usability experts, experienced developers and system designers, scholars and other stakeholders for simulated use of systems or applying expertise.	Detection of usability problems expressed as interface problematic features or as gaps during task execution.	Usability (effectiveness, efficiency, satisfaction).
Other user participation methods ▪ critical incident reports ▪ virtual reference	Continuous communication with the users and structured and methodological recording of the problem encountered.	Detection of usability problems expressed as interface problematic features or as gaps during task execution and management of content related requests.	Usability (effectiveness, efficiency, satisfaction). Resource attributes (currency, level, format etc)

5. Discussion

In this paper we proposed a three dimensional framework for the evaluation of user interaction in digital libraries. The main observation is that the user interaction depends on the various attributes of the digital library components and their relationships. The concepts of usability, usefulness and performance have been introduced to cover the need for monitoring and measurement. Still much work is needed for the development of an exhaustive and detailed list of metrics and for the resolution of the evaluation requirements.

Setting an evaluation framework will not be useful, if it isn't adaptive to particular details and cases. Bertot states that *"evaluative approaches tend to be tailored to particular needs of an organization"* [27] and despite that this statement concerns the physical or hybrid libraries, we believe that it is also valid in the case of digital libraries. The applicability of the appropriate methods depends on the context and the characteristics of the developing organization, the mission of the digital library, the available resources (infrastructure, human resources) etc. Most of the requirements offer alternatives, e.g controlled or natural environment, which can conclude to many different variations and may correspond to discrete features of the organization.

Establishing evaluation requirements would be beneficial for each digital library evaluation project. One possible suggestion is the development and the participation to testbeds. Testbeds examine the adaptability of any proposed framework by

observing the same object under different conditions. Multiple organizations, with different infrastructures, placed in different -wider- contexts, with different equipment and techniques, would add each one of them a small part in the puzzle of digital library interaction. The most indicative example is the TREC test collection, which is available to the attendees of this conference series and aims to evaluate the different information retrieval approaches [28].

Although it is anticipated that the digital library interaction will move towards more entertaining forms and new assessment and evaluation techniques will be proposed [29], we still need to have a clear image of what consists a successful interaction in the digital library environment. Evaluation is a mean to this clarification that will lead digital libraries to be useful and usable. Digital libraries are destined to serve user communities' task and needs and their core functions are those that achieve this destination.

A great amount of work is needed on the third dimension of the evaluation framework, namely the performance evaluation. The -now inactive- Interactive Track [30] of TREC was evaluating information retrieval in terms of user efficiency (if he completed his task), user effectiveness (in what time) and user satisfaction. Instance (or aspectual) recall measurement [20] was firstly proposed by Interactive Track in 1995 and uses the perceived relevance of information search results against the number of a specified subject. In simple words, instance recall measures user satisfaction of an information retrieval action, as well as the performance of the user himself. Although much work has been done towards the development of user centered performance evaluation methods, still much is needed to explore the performance impact in interaction.

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