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Toward Contextual Information Retrieval: A Review And Trends

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Abstract

With the growth of electronic data and the expansion of the World Wide Web (WWW), many classic existing retrieval models and systems ignore information about the actual user and search context. Due to the constraints imposed by this fact, context has received more attention in the information retrieval (IR) literature and its interactions over the past decade. In this paper, we emphasize on the importance and implications of context in information retrieval and how can it affect the retrieval systems to operate and behave more intelligently; we highlight some emerging trends of context; we present variety of practical uses of context along with its taxonomies and levels; we discuss how can we model context by these systems along with proposing some practical recommendations to enhance this research area for future research.

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1. Introduction

With the continuous growth of the size and the availability of electronic data and the expansion of internet technology, users can laboriously find and satisfy their information need in some situations, which may pose a permanent and serious challenges to current search technologies in the future. This challenge lead to an increasing

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research interest in contextualizing research to the aim of overcoming the limitations of many retrieval systems that have been mostly context free. The context consists of many factors such as cognitive and social ones that are related to a user's intentions, tasks and needs. It is within the interaction between user and these systems, that divulgence of user context models, is revealed. The concept of context [12], [13], has been long known as being very important in a variety of fields, such as information retrieval [4], [14], [15], [16 Lawrence] [2], [4], [1], [3], [5], automatic image analysis [17], [18], mobile and pervasive computing [19 Brown], [20], [21], [22], computational linguistics [23], [14], [24]. Since context covers a vast landscape of research, we will only cover a part of this landscape in this article, considering only works on the introduction of context in information retrieval (IR) where there is a growing interest in improving the search process towards the user needs by using the context [31]. Hence, the need of understanding this context within the IR interaction itself is important. Earlier, Dervin [8] considered context as an “unruly beast” because of the difficulties involved in defining methodological control on it. Vakkari [9] describes context as a ‘situation’ in his first International Conference on Information Seeking in Context (ISIC). In these past decades, the concept of context in information retrieval has been studied and discussed through numerous initiatives such as the IRIX workshops[†]; the monograph by [7] Ingwersen and Järvelin (2005), the HARD and ciQA tracks at TREC[‡] and the IiX conference series[§]. Indeed, recently, many information retrieval systems and search engines research works have integrated the concept of context to improve the retrieval performance [1], [2], [3], [4], [5], [6], [11], [25]. However, despite this increasing attention to “context” in IR, there is no clear definition about the concept of context, or its constituent elements, or its models, or its implications, which have noteworthy relationships with IR processes.

The goal of this paper is to present an overview of the theoretical and experimental works which addresses the context in IR. In order to better frame this work, in the next section, we first define the notion of context; we show its importance, implications and uses in information retrieval field; in section 3, we present the salient variety of context categories or taxonomies, how to modeling context, context uses, and his implications to IR; for each category of context, we give a brief summary of recent works that have been done in this field; in section 4, we discuss some challenges in Modeling context, and we propose some practical recommendations to enhance this task. Finally, we conclude with a conclusion and some perspectives.

2. The notion of context in IR

Using context for search is not a new idea. Several existing IR systems utilize the notion of context [5], [6], [11], [25], [1], [2], [3], [4]. However, in order to use context effectively in information retrieval systems, it is necessary to understand what context is and how it can be used. In Collins Cobuild English Language Dictionary [27], the prevalent meanings of the term include the following: First, the context of something consists of the ideas, situations, events, or information that relate to it and make it possible to understand it fully. Second, if something is seen in context or if it is put into context, it is considered with all the factors that are related to it rather than considered on its own, so that it can properly be understood. Third, if a remark, statement, and so on, are taken or quoted out of context, it is only considered on its own, and the circumstances in which it was said are ignored. Therefore, it seems to mean something different from the intended meaning [27]. Earlier, Dervin [8] considered context as an “unruly beast” because of the difficulties involved in defining methodological control on it. Vakkari [9] describes context as a ‘situation’. In [13] Edmonds defines context as an abstraction of an aspect of a heuristic for the learning and application of knowledge: *“the abstraction of those elements of the circumstances in which a model is learnt, that are not used explicitly in the production of an inference or prediction when the model is later applied, that allow the recognition of new circumstances where the model can be usefully applied.”* Dey & Abowd [28] define context as follows: *“any information that can be used to characterize the situation of entities (e.g. a person, a place or an object) that are considered relevant to the interaction between a user and an application, including the user and the application*

[†] See <http://ir.dcs.gla.ac.uk/context/>

[‡] See <http://trec.nist.gov/>

[§] See <http://iiix2010.org/>.

themselves". Another definition of context is given by Sato [30] as "a pattern of behavior or relations among variables that are outside of the subjects of design manipulation and potentially affect user behavior and system performance". According to Dourish [29], *context* may be defined in two perspectives: the first one describes it as a representational problem where it is viewed as a form of information that is delineable, independent and stable of the activity. It consists of implicit attributes that describe the user and the environment in which information activities occur., The second perspective defined it as an interactional problem and presents context as arising from the activity, from which it can't be separated. Ingwersen & Jarvelin [7] say that "*There are social, organizational, cultural as well as systemic contexts, which evolve over time*". Later, Ruthven [32] provides another definition: context is "*a complex set of variables describing our intentions, our personal characteristics, the data and systems available for searching, and our physical, social and organizational environments*". In [34] Crestani and Ruthven define the concept of context particularly in the information retrieval field as follows: '*context affects all aspects of information retrieval. A searcher's context affects how they interact with a retrieval system, what type of response they expect from a system and how they make decisions about the information objects they retrieve*'. Thus, since context depends on previous knowledge, we can say that "*the context is not explicit, not trivial and not static but it is a dynamic concept composed of many factors like users, situations, devices, locations, environments, time and more*", these factors will influence how we use an information retrieval system and how we evaluate its performance.

3. Contextual Information Retrieval Systems

Most classic information retrieval systems "IRS" use statistical methods based on the frequency of occurrences to retrieve relevant documents or either use linguistic or semantic methods. However, the design of these systems has ignored the context, especially the context of a user who is using this system (see Fig. 1). For example, if the search is made by a child, a suitable answer is presenting information that is acceptable for the child's age and his understanding level and avoid the complex answers. Consequently, it is necessary for IR'S to face challenges associated with the individual differences that exist between users, their tasks and goals. This fact involves a crucial problem nowadays as the information is authored and exploited by millions of different user's profiles, each one with different knowledge, backgrounds, preferences leading to different search contexts. Thus, to overcome these challenges, the retrieval of information should depend on many factors like: history of interaction, task in hand, time, place and a variety of other factors or variables that are not explicit but implicit in the interaction and surrounding environment, namely the context. These factors can be graded as dimensions, taxonomies or categories of context. In the following paragraph, we give an overview of some prominent previous related works.

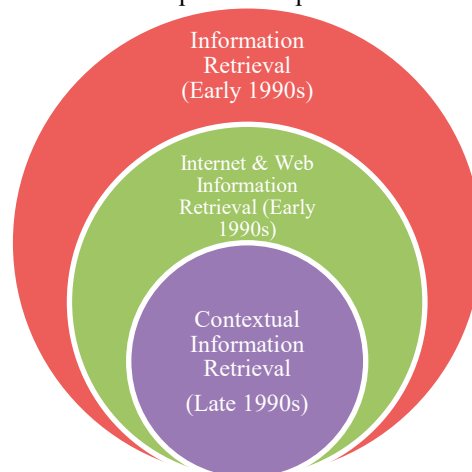


Fig. 1. Evolution of information retrieval systems

3.1. Context categories or taxonomies

Many contextual categories or factors may affect the use of an information retrieval system and the evaluation of its

performance. Several researchers have presented these categories as follows:

In 2000, Dey & Abowd [28] classify the context information based on the entities in which the context is evaluated and on the categories of context. Three entities are defined: (1) *people* (including individual or groups, co-located or distributed), (2) *things* (e.g. physical objects or software), (3) *places* (geographical space).

In 2002, Goker & Myrhaug [37] present a context in five main categories: (1) *the environmental context* that captures the entities that surround the user (things, services, temperature, light, humidity, noise, and persons). (2) The personal context consists of physical and mental information about the user. (3) *The task context* is about what the user is doing, tasks, activities and his goals. (4) The social context that describes the social aspects of the current user context, such as information about friends, neutrals, enemies, neighbours, co-workers and the (5) *the spatio-temporal context* which describes aspects of the user context related to the time and spatial extent for the user context.

In 2003, Kofod-Petersen and Aamodt [39] proposed an open context model as a part of “Ambisense project”, which was concerned by information retrieval via mobile devices. The taxonomic structure of context includes 5 main categories (See Fig. 2):

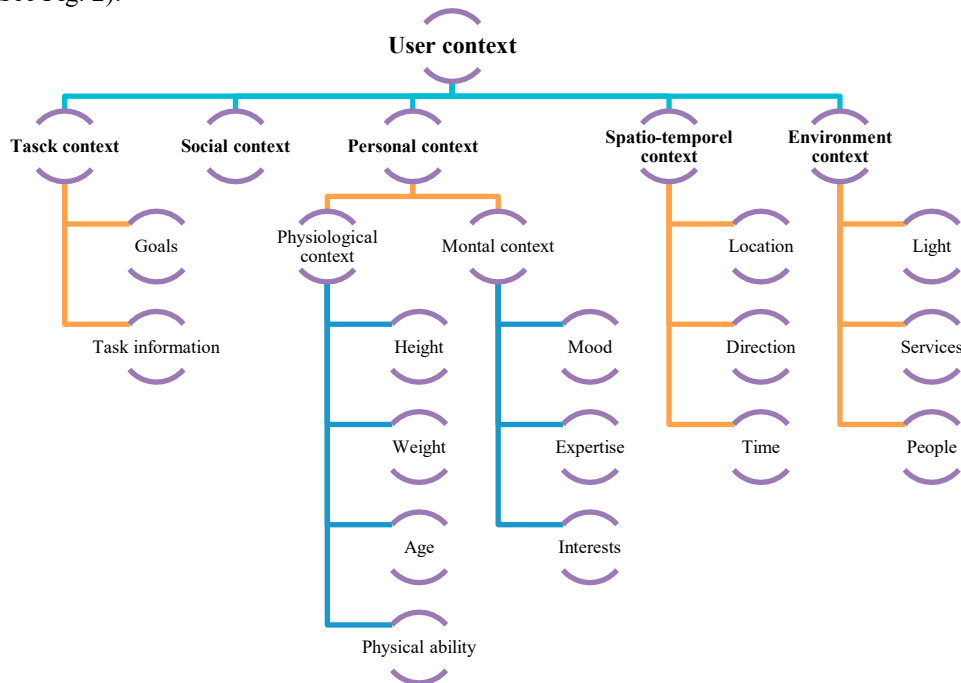


Fig. 2. Ambisense model of context [39]

i) *Task context*: The task context describes what the user is doing, it can describe the user’s goals, tasks, activities, etc. ii) *Social context*: describes the social aspects of the user, such as information about friends and relatives, the role the user plays, etc. iii) *Personal context*: this part describes the mental and physical information about the user, such as mood, expertise, disabilities, and weight. iv) *Spatio-temporal context*: this type of context is concerned with attributes like: time, location, and movement. v) *Environmental context*: This part captures the users surrounding, such as things, services, light, people, and information accessed by the user [39].

In 2006, a nested model of context for IR with six categories or “dimensions” (see Fig. 3) was presented by Ingwersen & Jarvelin [36]. According to [36], the (1) *Intra-object structures* refer to context obtained from terms, phrases, image features, pixels, sentences, paragraphs, sections; (2) *Inter-object contexts* are concerned with the properties of documents, like links, citations, document clusters defined of various features; (3) *Interaction/session context* which is expressed by search/authoring process (*evidence*, e.g., eye/mouse movements, Work Task descriptions, explicit Relevance Feedback, search task path); features of algorithmic IR processes, auto-indexing key-strings; (4) *Individual context*, dependent on central components (subjective): actor, current work, task perception ... ;(objective): engine logic/algorithms, interface functionality; (5) *Collective context*, dependent on central components: (local) sociocultural and organisational structures/conditions: like domain vocabulary, natural work tasks,

organizational preferences, several searchers' Work Task perceptions, socio-cognitive relevance assessments and recommendations, implicit Relevance Feedback behaviour; (6) *Infrastructural contexts* :infrastructures influencing (not necessarily always in a remote way) all actors, components and interactive sessions, network type, speed, censorship, economic constraints ...; and the (7) *historic context* operates across this stratification, i.e., the history of *all* participating actors' experiences, forming their expectations. All information retrieval processes and activities are under influence of this temporal form of context [36].

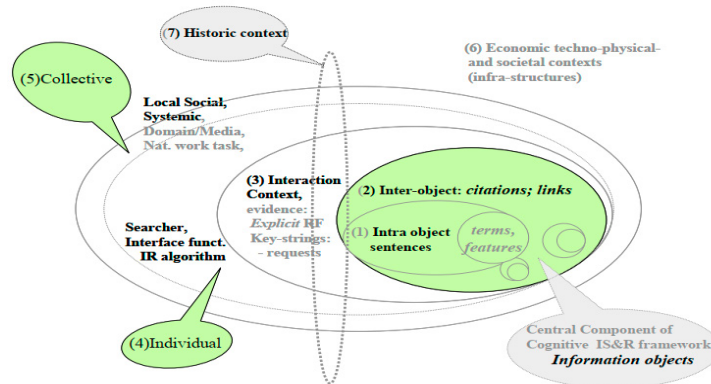


Fig. 3. Nested model of context types centred on Information Objects of an IR system [36]

Later in 2008, Mansourian [38] identify five categories as the main contextual elements which affect search performance of end users. These categories include: (1) *web users' characteristics* that includes three subcategories which are feelings, thoughts and actions of the user during the search procedure and after having search results, which might be satisfactory or unsatisfactory for him/her; (2) *type of the search tool*; (3) *search topic* which can be divided into work-related and everyday life searches; (4) search situation including four subcategories which are place of search, type of search, immediacy and importance of search; and (5) *features of the retrieved information resources* that refer to three subcategories which are level of provision, searchability and presentation format.

In 2009, Tamine et al. [40] proposed five context specific dimensions, listed below (see Fig. 4):

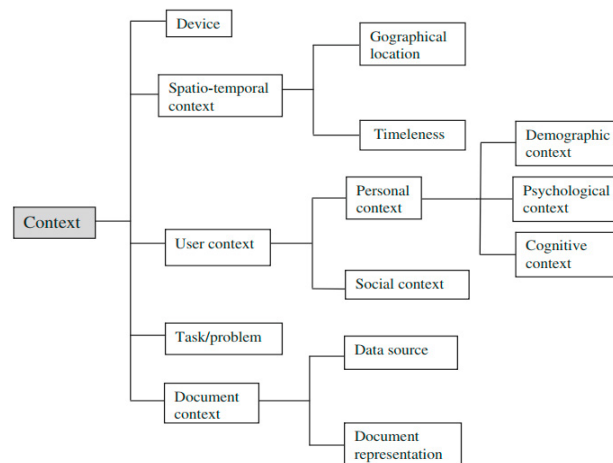


Fig. 4. The multi-dimensional concept of context in an IR system [40]

In Fig. 4, Tamine et al. [40] introduce the context of the information access device in addition to the document context, the spatio-temporal context, the user context and the task context. This taxonomy covers all the past discussed categories in a more organized and detailed way.

In 2012, Melucci considers four categories of context in his computational framework: (1) *content* refer to the

informative content and relationships between queries and documents, (2) *geographical*: any variable that having some relationship with space location, (3) *interaction* that is observed over time during the interaction between users and IR systems, and (4) *social variables* refer to user communities or groups.

In 2017, O'donnell [6], in his developed context data search, considers many context categories like: user or community characteristics context, content context, user cognitive context, physical or virtual location context, time, virtual object or idea, device, philosophy, goal.

More recently in 2018, Tseng & Braginsky [1] invent a system that provides context relevant search for a user based on his: interest, location, content, associated timing.

Generally, several of viewed literature shares some of context taxonomies; however as mentioned above, the taxonomy of Tamine et al. [40] covers almost all the dimensions discovered and studied in the IR systems based on the context. Although, these taxonomies attempt to meet the needs of the modeling and to consider the characteristics of the web of today; we can see carefully that there is still some ambiguity in the definition of certain dimensions of context.

3.2. Context in information retrieval systems

The imposed demand for using contextual approaches in information retrieval systems 'IRS' is that, IRS will be more precise and provide better results to our information need when they depend on different search contexts. In IRS, the context depends mainly on some of related categories (listed above) associated to the current situation of retrieval. Generally, Fig. 5. presents the basic architecture of a context-aware, also called contextual IRS given by [40], where we notice that this architecture is based on two main axes: (1) *context modeling* and (2) *contextual retrieval*. In the following paragraphs, we give an overview of previous related works.

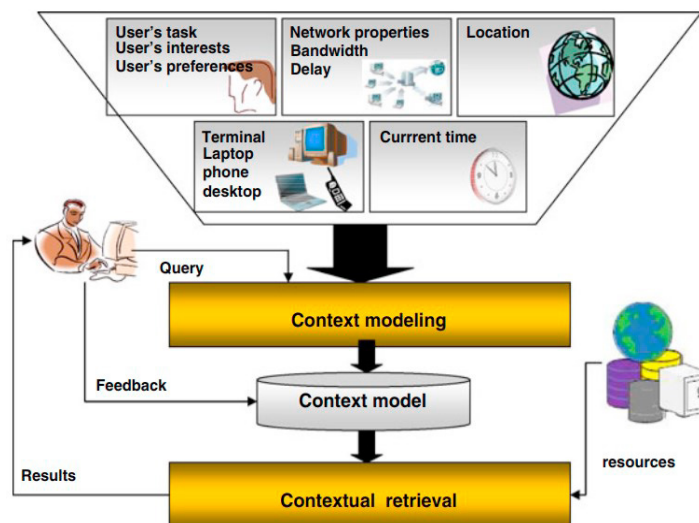


Fig. 5. A basic architecture of the contextual IRS [40]

3.2.1. Context modeling

Context modeling has been long acknowledged as a key aspect in information retrieval. The aim of this task is to address two main problems: how to model the user's context, and how to exploit it in the retrieval process in order to provide the user with information that is of most value in his context. Effectively, in contextual IRS, user's behavior can be predictable grounded on his past interactions with the system. Consequently, to predict the user needs, the system must select and use only those preceding interactions that were offered within the same context [41]. Thus, the effectiveness of the system depends strongly on the available quality and quantity of information and its preferences

about the user. In order to make this information available, three key points characterize a context modeling approach that should be undertaken as processes: (1) *the acquisition process* for capturing the information characterizing the user context by involving several techniques to build it which is called usually user profile (2) *the representation process* aimed at formally representing the acquired information, to facilitate the access to the information and its use by IRS and (3) *updating process* is finalized at learning the changes of the user preferences in time.

3.2.2. Contextual retrieval

In [35], contextual retrieval is defined as '*combining search technologies and knowledge about query and user context into a single framework in order to provide the most appropriate answer for user's information needs*'. Thus, contextual IR aims at optimizing the retrieval accuracy by involving two related steps: appropriately defining the context of user information needs, commonly called search context, and then adapting the search by taking it into account in the information selection process [35]. Moreover, IRS will be more intelligent, dynamic, flexible and effective at changing their results in different contexts, they will be also more adaptive to the user's information need and its preferences which make the search task easier. Indeed, the inclusion of context in IRS reduce the complexity of the retrieval process and increase its performance especially when we use a quality contextual variables or factors [18], [29], [7]. In Table 1 we illustrate a comparison between classic information retrieval systems versus contextual information retrieval systems.

Table 1. Differences between classic information retrieval systems versus contextual information retrieval systems

Classic Information Retrieval Systems	Contextual Information Retrieval Systems
- Context free.	- More intelligent.
- Focus on the topic of the search	- Need a Pre-knowledge information.
- Ignore the specific user's search context	- Better match results.
- No supporting of individual differences that exist between users.	- Individual or group based
- Static.	- More flexible with differences of the context.
- Low understanding of results.	- Dynamic
- No cognitive view	- Cognitive; Meaningful, Comprehensive.
- Difficulty in evaluation	- Reduce the complexity of IRS process.
	- Support the predicting of information need.
	- More sophisticated methods to measure the relevance
	- Short queries are disambiguated
	- Optimizing the retrieval accuracy
	- Social interaction is encouraged
	- High retrieval precision is improved

3.2.3. Uses of context in IRS

The taxonomy presented by Ingwersen & Jarvelin's [36] is the most appropriate to many context IRS. But, it does not cover uses of context, only Dey & Abowd [28] has propose such use. In this section we present a brief summary of some categories of uses of context in IR. The context can be used in: (1) *ranking*; (2) *user interface* which divided in two subcategories: the interface associated with the specification of the user's information need and the presentation of the result set. This last category is also divided in document surrogates (e.g. snippet - short summary of the document), query term hits within document (e.g. keyword-in-context snippets), categories for results set context and other type of strategies; (3) *indexing & searching*; (4) *relevance feedback* (RF) which is divided in global and local methods, global methods include query expansion/reformulation based on collection-independent knowledge

structures and local methods, like pseudo relevance feedback, implicit relevance, adjust the query with information from the documents that belong to the result set of the initial query and (5) query expansion.

3.3. Context levels in IRS

To better understand the integration of context in IRS, the context can be seen in many essentials levels or aspects such as:

- *Information environment level*: context can be interpreted as the information environment within which information behaviours take place.
- *Information seeking level*: the information seeking context level comprises the goal(s) that a person is trying to achieve, or his intentions as they relate to a problematic situation.
- *IR interaction level*: explores the user–system interaction within search sessions, Where the role of feedback relevance, judgments as related to characteristics of users' situations can be investigated
- *Query level*: can be described as a linguistic level of context which explores IR system performance on user queries, including query disambiguation as terms in the query are interpreted correctly or incorrectly by the system depending to the context assigned to them.

4. Discussion and recommendation

According to the previous sections, contextual information retrieval systems are based on different definitions of the core concept of user's context and on various user's context modeling approaches, in the aim of providing the most useful information need to the users along with considering their context. To achieve this goal many frameworks are proposed by several authors [1;2;40;42;30]. A common major challenge in these frameworks is: the modularization of the user context, where there is a difficulty of capturing and representing knowledge about user context; especially that the context is extremely dynamic and can changes constantly even for the same user or during the same search in process. This means that even on the basis of correctly learned user preferences, the IRS could make wrong suppositions or get importunate, the same case can happen when user have multiple interests. Independently of the decision about how to capture and exploit the knowledge of the user's preferences, another interesting aspect which emerges in contextual IRS is that, the availability and accessibility of a model of context (which may represent both user's preferences, and others contexts factors); Since contextual IRS strongly based on user related and user personal information, the discussed aspect rise another issue which is the user's privacy that should be preserved, many users don't prefer to share the information that concerns their private life with some IRS. Generally, the modelling and use of contexts for the adaptation of the information to the user's current situation and current information needs can cause several other challenges. Thus, we suggest some context model's requirements that address some of discussed issues and others. In general, (1) first, in order to improve retrieval results, using the long-term user interest profiles can be efficient, to cope with this, a context-modelling framework has to identify all relevant and useful contextual categories; (2) the knowledge about the actual context of a user should be used for 2 aims: first to enhance any information created, modified, or published by the user, and second to offer information created, modified, or published in contexts similar to the current user's context (3) after the system allow users to explicitly provide context information, at the same time a context should basically be recognised automatically; (4) the context-modelling framework should rank dynamically any important contextual dimensions used to well performing the similarity match; (5) the notion of time is very important on term of recognising the current context and on retrieving information relevant to this context; (6) to address the problem of model of context availability and more generally, the availability of more structured context models is to define user-dependent aggregation schemes defined as linear combinations where weights of relevance context dimensions are automatically computed based on the user-specified priority order over the dimensions [43].(7) for the issue of privacy , the client-side applications can be useful where some architecture are used to enforces user privacy on social networking sites by shielding a user's personal information from the site and from other users that were not explicitly authorized by the user [44] [45] [46].

5. Conclusion and perspectives

Context becomes a common notion in Information Retrieval and has been recognized as a major challenge in the field. In this paper, we provided an overview of the evolution of IR systems from the classic to the contextual scope. We have presented the concept of context, the variety of its categories, levels and uses. We showed also how can we model the context in the IR process based on different definitions of the core concept of user's context; finally, we have discussed some issues of modelling the context in information retrieval and proposed some practical recommendations to enhance this research area for future research. Although, a considerable number of works focused on contextual IR systems, some important challenges for the research community are still remaining. For this reason, more attention should be given to the problematic of context in order to discover new dimensions and to improve more the search engines by addressing the following problems: ways to exploit shared contexts and contexts over time; common problems in contextual IRS and ways to resolve them; ways to enhance the modelling of user context; evaluation methods.

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