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Review

A systematic review of scholar context-aware recommender systems

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ABSTRACT

Incorporating contextual information in recommender systems is an effective approach to create more accurate and relevant recommendations. This review has been conducted to identify the contextual information and methods used for making recommendations in digital libraries as well as the way researchers understood and used relevant contextual information from the years 2001 to 2013 based on the Kitchenham systematic review methodology. The results indicated that contextual information incorporated into recommendations can be categorised into three contexts, namely users' context, document's context, and environment context. In addition, the classical approaches such as collaborative filtering were employed more than the other approaches. Researchers have understood and exploited relevant contextual information through four ways, including citation of past studies, citation of past definitions, self-definitions, and field-query researches; however, citation of the past studies has been the most popular method. This review highlights the need for more investigations on the concept of context from user viewpoint in scholarly domains. It also discusses the way a context-aware recommender system can be effectively designed and implemented in digital libraries. Additionally, a few recommendations for future investigations on scholarly recommender systems are proposed.

1. Introduction

Recommender Systems (RSs) have been an area of substantial research interest since the mid-1990s (Felfernig & Burke, 2008). In the last decade, RSs had been investigated and implemented in various application domains, including knowledge management, e-commerce, e-learning and e-health (Verbert, Lindstaedt, & Gillet, 2010).

The dramatic data increase in *Digital Libraries* (*DLs*) has necessitated the use of RSs as an appropriate tool for facilitating and accelerating the process of information seeking (Porcel & Herrera-Viedma, 2010). Scientists prefer to have most of their required information at their fingertips. They usually input keywords to retrieve the desired scientific information in DLs, but the results may not always be what they would expect. Hence, the retrieval of relevant information has been a time-consuming task for most of them. Consequently, providing proper information is a significant factor for an effective DL in a scientific environment. Libraries try to apply intelligent personalised systems such as RSs (Mönnich & Spiering, 2008) to support users by offering relevant resources based on their interests and preferences (Sikka, Dhankhar, & Rana, 2012). RSs can manage information overload by filtering and personalising data according to users' needs (Adomavicius, Sankaranarayanan, Sen, & Tuzhilin, 2005; Pommeranz, Broekens, Wiggers, Brinkman, & Jonker, 2012); thus, RSs normally collect data about users' activities and build user models to filter the preferences expressed either explicitly or implicitly (Baltrunas, Ludwig, Peer, & Ricci, 2012).

In recent years, RSs use the information describing users' situations such as location, time, and task in order to generate more relevant and personalised recommendations (Adomavicius & Tuzhilin, 2011; Asabere, 2013). For example, the resources recommended to an undergraduate student searching for "Fuzzy method" for his class assignment may be different from those recommended to a graduate student writing a research paper on the same topic. This is due to the different requirements of the tasks they are working on and the different levels of formal education, which are considered as contextual information.

Using contextual information has been considered as a main source of accuracy of recommendations (Adomavicius & Tuzhilin, 2011; Baltrunas, 2008). Researchers emphasise applying contextual approaches in order to recommend items to users based on certain circumstances (Baltrunas & Ricci, 2009; Kaminskas & Ricci, 2011). However, the variety of application scenarios and user

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requirements cause difficulties in presenting an unanimous definition of contextual information for all *Context-Aware Recommender Systems* (*CARS*) (Yujie & Licai, 2010). Moreover, to predict accurate recommendations for users of a specific domain such as DLs, it is essential to understand and exploit the relevant contexts of users, which lead to creating intelligent recommendations. Therefore, the aim of this study is to carry out a literature review on RSs for the academic DLs in order to:

(a) Identify the contextual information that has been adopted for making recommendations in the academic DLs.
(b) Identify the approaches that have been used to adopt contextual information for making recommendations in the academic DLs.
(c) Explore how the relevance of contextual information to recommendations for an academic domain has been understood by researchers before applying it.

We conducted this review based on the guidelines by Kitchenham and Charters (2007) for performing systematic literature reviews in software engineering. We explain more about the methodology of our review in Section 4. The rest of the paper is organised as follows. We discuss a few definitions of context from various points of views and provide recommendation approaches in Section 2. The related works are presented in Section 3. The methodology of this study is presented in Section 4. We report and discuss the results from performing the review in Section 5. The results are structured according to the research questions.

2. Background

2.1. What is context?

Many definitions of context have been proposed in various disciplines, including computer science (primarily in artificial intelligence and ubiquitous computing,), information retrieval, cognitive science, linguistics, philosophy, social science, psychology, and organisational sciences (Adomavicius & Tuzhilin, 2011); it is beyond the scope of this research to review all of them. However, from a general point of view, the Oxford Advanced Learner's Dictionary mentions that context is "a situation in which something happens and that helps you to understand it" (Crowther, 1995). Likewise, according to the Webster's dictionary (Webster, 2006), "Context is a situation in which something happens: the group of conditions that exist where and when something happens".

In the late twentieth century, the epistemological contextualisation was developed by philosophers. This theory indicates that the standards of knowledge and justification change with the context. Particularly, understanding of context is necessary for better comprehension of a situation since when the context shifts, the knowledge about the situation will shift as well (Craig, 1998).

The term context appeared in computer science in the late 1980s (Hong, Suh, & Kim, 2009), and the idea of context awareness in computing was introduced by Schilit in 1994 (Brown, Bovey, & Chen, 1997) in order to increase the richness of communication and provide more useful computational services (Dey, 2001). Since then, many studies in the field of computer science tried to define the term "context". Some studies present parametric definitions that stipulate context as a set of parameters such as time, temperature, lightness, and speed, while others define context generally and try to explain context and its territories. For example, Schilit and Theimer (1994) defined context as location, identity, nearby people, and objects. In a similar definition by Brown et al. (1997), context consists of location, identity, nearby people and objects and season. Meanwhile, (Pascoe, 1998) explained that context corresponds to the following questions:

1. Where are you?
2. Who are you with?
3. What resources are nearby?

One of the most cited definitions from a computer science viewpoint was offered by Abowd et al. (1999) as shown by Fig. 1. They expressed that context is any information that can be used to characterise the situation of an entity. They categorised context into four dimensions: location, identity, time, and activity. In this definition, there are two context levels: primary contexts, which are the four mentioned dimensions and secondary contexts gained from primary contexts. As an illustration, many pieces of related information such as phone numbers, addresses, email addresses, birth date, etc., can be acquired from the location of an entity. Such information acquired from primary contexts is numerated as secondary contexts.

In another computer science point of view, (Lieberman & Selker, 2000) interpreted context as "everything" that "affects the computation except the explicit input and output", including the state of user, physical environment, computational environment, and history of user–computer environmental interaction. Dourish (2004) expressed the context as "the features of the environment within which the activity takes place", and indicated that it is separate from the activity itself. He assumed that the context was defined with a predefined set of observable attributes, the structure of which does not change significantly over time. As shown in Fig. 2, (Haseloff, 2005) presented a model of contextual factors based on Object Oriented (OO) concepts and Unified Modelling Language (UML), including surroundings, state, location and reachability.

Bazire and Brézillon (2005) identified the main components of context by analysing 150 definitions coming mainly from the web in different domains. However, they concluded that it is difficult to reach a consensus on what exactly context is. Thus, trying to reach a consensual definition for context is an ineffectual effort since the concept of "context" evokes different impressions in each reader and context may include almost everything (Kocaballı & Koçyiğit, 2007). Furthermore, it is difficult to present a definition that encompass all the aspects it refers to Tamine-Lechani, Boughanem, and Daoud (2010).

Adomavicius and Tuzhilin (2011) discussed the concept of context in recommender systems and explained how it is defined in different fields related to RSs such as data mining, e-commerce personalisation, databases, information retrieval, ubiquitous and mobile context-aware systems, marketing, and management. They confirmed that context is a multifaceted concept and there is no commonly accepted definition of context in different fields. The definition of context in RSs was investigated by Verbert et al. (2010) while contextual information is considered as any additional information that has a direct impact on the relevance of recommendations. The above definitions demonstrate that the concept of context in RSs is a crude concept. Besides, the concept of context in various domains like academic DLs differs from other domains. In other words, the nature of academic domain influences recommendations. Creating recommendations for users in an academic domain to cater to their needs and tasks needs more analysis of contextual information affecting decision-making in this

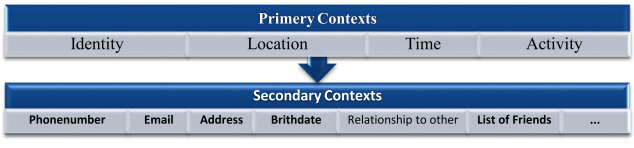

Fig. 1. Context levels offered by Dey and Abowd.