Domain of Application in Context-Aware Recommender Systems: A Review

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ABSTRACT
The purpose of this research is to provide an exhaustive overview of the existing literature on the domain of applications in recommender systems with their incorporated contextual information in order to provide insight and future directions to practitioners and researchers. We reviewed published journals and conference proceedings papers from 2010 to 2016. The review finds that multimedia and e-commerce are the most focused domains of applications and that contextual information can be grouped into static, spatial and temporal contexts.

Keywords: Context-aware, Context, Domain of application, Recommendation.

I INTRODUCTION
Internet being the primary source of information helps users to acquire information whenever, wherever, and whatever they wish, according to their interests. However, the overwhelming amount of information that is available on the internet leads to the problem of information overload, where researchers can easily get lost finding information that may be associated with their interest (Hawalah & Fasli, 2014).

Recommender system (RS) emerged over the last decade to remediate the problem of information overload by collecting information on the preferences of its users for a set of items (Bobadilla, Ortega, Hernando, & Gutiérrez, 2013).

At the emergence of RS in the 1990s, two dimensional recommender systems were the predominant approaches in predicting users’ interests. However, more recently, researchers aimed at developing systems with the ability of recommending items to users in certain circumstances, with an incorporation of contextual information into the two-dimensional recommendation process being leveraged (Panniello, Tuzhilin, & Gorgoglione, 2014).

Recommender systems become appropriate tools for facilitating and accelerating the process of information seeking. (Bobadilla et al., 2013) pointed out that developing applications is the focus of the current recommender system researches, especially with the current age of big data.

Despite the acceptance of the concept of recommender system by many developers from different domains of applications such as music (Hariri, Mobasher, & Burke, 2012), movies (Colombo-Mendoza, Valencia-García, Rodríguez-González, Alor-Hernández, & Samper-Zapater, 2015), tourism (Teze, Gottifredi, García, & Simari, 2015), e-commerce (Panniello et al., 2014), learning (Benlamri & Zhang, 2014), news (De Pessemier et al., 2015), etc. Yet, none to our knowledge a single paper that identify the various domains of applications in recommender systems with their incorporated contextual information.

In this paper, we address various domains of applications and the different contextual information incorporated by the researchers in each domain. This will help in developing a generic framework that will be of maximum flexibility for all context-aware recommender systems. It may also justify whether the incorporated contextual information are well enough for recommending tailored services to users or more extensive research need to be done in such directions.

The rest of the paper is organised as follows. Section II presents related work. Our methodology is presented in section III. Section IV is the results of our review and finally the conclusion and future work are explained in section V.

II LITERATURE REVIEW
It has been a decade since the field of Computer Science embraced the concept of context-aware recommender systems (CARS) which has being researched extensively in various domain of applications such as movies, music, e-commerce, etc. Despite these numerous studies, we could not locate a paper that identify the different domains of applications with their incorporated contextual information.

(Park, Kim, Choi, & Kim, 2012) reviewed 210 articles on recommender systems from 46 journals published between 2001 and 2010. The authors examined and classified those papers by the year of publication, the journals in which they appear, their application domain, and their data mining techniques. The authors
also categorized the 210 papers into eight application fields and eight data mining techniques.

According to the review, the majority of the research papers were related to movie and shopping and least attention has been paid to image processing field. In this paper, we do not only identify the domain of applications in recommender systems but also identified their incorporated contextual information.

Journals and conferences that were published from 2000 to 2007 were also reviewed in (J.-y. Hong, Suh, & Kim, 2009) using a keyword index and article title search. The authors suggest a new classification framework of context-aware systems, which consists of five-layer architecture, concept and research layer, network layer, middleware layer, application layer and user infrastructure layer.

In the application layer, they identified five domains of applications of tower guide, information systems, communication systems, m-commerce and web services. Their work is limited to identifying the contextual information constituted in each domain.

A review has also 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 2001 to 2013 (Champiri, Shahamiri, & Salim, 2015). The result of their review revealed that contextual information incorporated into recommendations could be categorised into three contexts, users’ contexts, document’s context, and environment context. Their work is limited to the domain of digital library, however in this paper; we identify the contextual information incorporated in different domains of applications.

Recommender systems was also examined systematically into the real-world applications domains and application platforms (Lu, Wu, Mao, Wang, & Zhang, 2015). The research identified eight different major application domains: e-government, e-business, e-commerce/e-shopping, e-library, e-learning, e-tourism, e-resource service, and e-group activity. In each domain, they mentioned several typical applications: digital product (tag, TV program, webpage, document, video, movie, etc.), physical goods (books, bags, etc.) and tourism that focuses on attractions and destinations, while others offer tour plans that include transportation, restaurants and accommodation.

III METHODOLOGY

The purpose of this research is to identify the domains of applications in recommender systems with their incorporated contextual information by examining the journals and conference proceedings papers that were published between 2010 and 2016 in order to provide researchers with insight and future directions.

In an attempt to perform an exhaustive search, we identify the bibliographic databases that cover the majority of journals and conference proceedings papers published in the field of computer science. These databases are ACM, IEEE, ScienceDirect, SpringerLink and Web of Science.

The searching process was performed based on the Boolean search criteria “(Context) AND (Recommender OR Recommendation)”. We extracted all the papers that mentioned context and recommender in the paper title and abstract.

We then review each paper and include only those that mentioned context and recommender in both the title and abstract and exclude any conference paper that has less than 10 citations for 2010-2013 papers and 5 citations for 2014-2016 papers.

Finally, 68 papers were selected and each paper was prudently reviewed and classified into its domain of application and exploring its incorporated contextual information.

IV RESULTS AND DISCUSSIONS

The importance of contextual information in recommender system was recognised for some time (Adomavicius & Tuzhilin, 2001), and as a result the context-aware recommender system field was formed. With the help of current technologies, researchers are able to detect the current context and activity of a user by analysing the data retrieved from different technological tools such as sensors, GPS, etc and which are used to provide personalised suggestions to users based on their recognized activities and contexts.

The distribution of the reviewed papers by year of publication from 2010 to 2016 is shown in Figure 1. It can be noted that publications related to context-aware recommender systems are increasing in an arithmetic progression. However, there is a tremendous increase in the year 2013.

From figure 1, the year 2016 has the lowest number of publications with total number of zero. This is of no
surprise as our review covers only publications between January 2010 and January 2016. It can also be inferred from figure 1 that a higher number of papers may be published at the end of 2016.

The results taken from our review showed that the domain of applications can be categorised into six major groups (Table 1), including e-commerce, e-documents, multimedia, places, travel and tourism, and others.

<table>
<thead>
<tr>
<th>Domain of Application</th>
<th>Incorporated contextual information</th>
<th>References</th>
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<tbody>
<tr>
<td>e-Commerce</td>
<td>URL, time of the year, current budget, mood, mental stress, gender, age, location, vicinity, category, seasonality, previous logs.</td>
<td>(Castro-Schez, Miguel, Vallejo, &amp; López-López, 2011; Chan, Chiu, &amp; Yu, 2011; Faraone, Gorgoglione, Palmisano, &amp; Panniello, 2012; Guo, Zhang, Thalmann, &amp; Yorke-Smith, 2014; Li, Chou, &amp; Lin, 2014; Lin, 2014; Lombardi, Gorgoglione, &amp; Panniello, 2013; Panniello et al., 2014; Shi, Ghedira, &amp; Marini, 2015)</td>
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<tr>
<td>e-Documents</td>
<td>Activity, background, technology, environment, device, time of the day, URL, gender, age, previous logs. Book (ISBN, title, author, publisher, date classification, description, keywords, format, language), Paper (title, authors, abstracts, keywords, URL, introduction main idea, conclusion, description, type of paper (journal, conference proceedings).</td>
<td>(Benlamri &amp; Zhang, 2014; De Giusti, Villarreal, Vosou, &amp; Martínez, 2010; De Pessemier et al., 2015; Hahn, 2011; Herlocker, Jung, &amp; Webster, 2012; Lutz, Thönsen, &amp; Witschel, 2013; Yoshikane &amp; Itsumura, 2013; Zarrinkalam &amp; Kahani, 2013; Zeng et al., 2012)</td>
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<tr>
<td>Multimedia</td>
<td>Location, crowd, time, mood, social, companion, mental stress, orientation, weather, age, gender, sensory data.</td>
<td>(Alhamid, Rawashdeh, Al Osman, Hossain, &amp; El Saddik, 2015; Alhamid, Rawashdeh, Dong, et al., 2015; Chen et al., 2010; Colombo-Mendoza et al., 2015; Durán, Laitakari, Pakkala, &amp; Perälä, 2010; Gallego, Woerndl, &amp; Huecas, 2013; Gantner, Rendle, &amp; Schmidt-Thieme, 2010; Hariri et al., 2012; Hussein, Linder, Galeke, &amp; Ziegler, 2014; Zheng, Mobasher, &amp; Burke, 2014)</td>
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<tr>
<td>Places</td>
<td>Current time, distance to available point of interest, companion, intent, nationality, location, current activity,</td>
<td>(Biancalana, Gasparetti, Micarelli, &amp; Sansonetti, 2013; Gallego et al., 2013; Hussein et al., 2014; Levi, Mokryn, Diet, &amp; Taft, 2012; Woerndl, Huebner, Bader, &amp; Gallego-Vico, 2011; Yuan, Cong, Zhao, Ma, &amp; Sun, 2015; Zheng et al., 2014)</td>
</tr>
<tr>
<td>Travel and Tourism</td>
<td>Time, location, companion, vicinity, social relations, current situation, intent, nationality, seasonality, budget.</td>
<td>(Bagci &amp; Karagoz, 2015; De Pessemier, Dooms, &amp; Martens, 2014; Gavalas, Konstantopoulos, Mastakas, &amp; Pantziou, 2014; Teze et al., 2015; Zheng et al., 2014)</td>
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Distribution of research papers by application fields is represented in figure 2. The majority of the research papers were related to multimedia (19 out of 68 papers, or 27.9%) and e-commerce (15 out of 68 papers, or 22.1%). This is because at the emergence of recommender system, multimedia (movie and music) and e-commerce have the higher number of practical applications than any other field.

Additionally, by having Movielens and LastFm as datasets for both movies and music respectively, encourage a development of applications in multimedia domain. It can be noted that travel and tourism scored the least number of publications (5 out of 68 papers, or 7.4%). However, from the review it can be noted that travel and tourism is a new concept that is now taking much attention in recommender systems, as the five publications are between 2014 and 2015.

![Figure 2 Distribution By Domain Of Applications](http://www.kmice.cms.net.my/)

Many researches focus on incorporating context into the recommendation process in different domains of applications with different contextual information. From our review, the contextual information adopted by researchers can be categorised into static, spatial and temporal contexts.

**Static contexts.** The static contexts are the contextual information that do not usually change over a period of time, but have an effect on the recommendation process. These are fixed information, such as age, identity, name, gender and other user profile information, including personal or demographic information and other generic interests that do not usually change over time.

**Spatial contexts.** The spatial contexts are the contextual information that formalise the environmental or geographical situation of both the users seeking recommendation and the items to be recommended. The most common example of this category is the location of the user and/or the item.

**Temporal contexts.** Temporal contexts are the contextual information that are meant for a temporary period. These are the dynamic contexts, such as the current goal, mood, location, situation, time, activity, choice, and social relation of a user seeking recommendations.

**V CONCLUSION AND FUTURE WORK**

This paper presents an extensive overview of the researches conducted on context-aware recommender systems. The theoretical contribution of our work is twofold. Firstly, we classified the previous researches according to their domain of applications and their incorporated contextual information. Next, our review revealed that the contextual information incorporated in recommender systems could be grouped into static, spatial and temporal contexts.

From our review, multimedia and e-commerce are the most focused domains of applications and that researchers usually incorporate one or two contextual information into the recommendation process, and the recommendation is either for a single individual or a set of the same items.

Therefore, we propose the need for an extensive research on developing a more flexible framework that will be used to incorporate as many contextual information as possible into the recommendation process and the recommendation should also cover group recommendations. We hope for this review to provide researchers and practitioners with some insight on the trend in the field of context aware recommendation systems.

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