

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 help 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 in 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 addresses 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, music, 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.

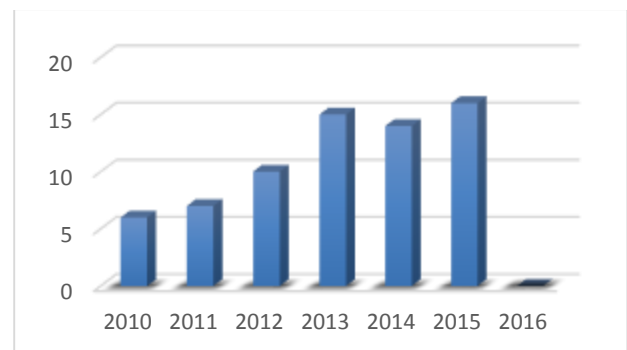


Figure 1. Distribution by Years

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 1 Domains of Applications with their Incorporated Contextual Information

Domain of Application	Incorporated contextual information	References
e-Commerce	URL, time of the year, current budget, mood, mental stress, gender, age, location, vicinity, category, seasonality, previous logs.	(Castro-Schez, Miguel, Vallejo, & López-López, 2011; Chan, Chiu, & Yu, 2011; Faraone, Gorgoglione, Palmisano, & Panniello, 2012; Guo, Zhang, Thalmann, & Yorke-Smith, 2014; Li, Chou, & Lin, 2014; Lin, 2014; Lombardi, Gorgoglione, & Panniello, 2013; Panniello et al., 2014; Shi, Ghedira, & Marini, 2015)
e-Documents	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).	(Benlamri & Zhang, 2014; De Giusti, Villarreal, Vosou, & Martínez, 2010; De Pessemier et al., 2015; Hahn, 2011; Herlocker, Jung, & Webster, 2012; Lutz, Thönssen, & Witschel, 2013; Yoshikane & Itsumura, 2013; Zarrinkalam & Kahani, 2013; Zeng et al., 2012)
Multimedia	Location, crowd, time, mood, social, companion, mental stress, orientation, weather, age, gender, sensory data.	(Alhamid, Rawashdeh, Al Osman, Hossain, & El Saddik, 2015; Alhamid, Rawashdeh, Dong, et al., 2015; Chen et al., 2010; Colombo-Mendoza et al., 2015; Durán, Laitakari, Pakkala, & Perälä, 2010; Gallego, Woerndl, & Huecas, 2013; Gantner, Rendle, & Schmidt-Thieme, 2010; Hariri et al., 2012; Hussein, Linder, Gaulke, & Ziegler, 2014; Zheng, Mobasher, & Burke, 2014)
Places	Current time, distance to available point of interest, companion, intent, nationality, location, current activity,	(Biancalana, Gasparetti, Micarelli, & Sansonetti, 2013; Gallego et al., 2013; Hussein et al., 2014; Levi, Mokryn, Diot, & Taft, 2012; Woerndl, Huebner, Bader, & Gallego-Vico, 2011; Yuan, Cong, Zhao, Ma, & Sun, 2015; Zheng et al., 2014)
Travel and Tourism	Time, location, companion, vicinity, social relations, current situation, intent, nationality, seasonality, budget.	(Bagci & Karagoz, 2015; De Pessemier, Dooms, & Martens, 2014; Gavalas, Konstantopoulos, Mastakas, & Pantziou, 2014; Teze et al., 2015; Zheng et al., 2014)
Others	Time, seasonality, sequentiality, role	(Bouneffouf, Bouzeghoub, & Gancarski, 2012; Codina, Ricci, & Ceccaroni, 2015; Gedikli & Jannach, 2013; Hidasi, 2015; Hidasi & Tikk, 2015; L. Hong et al., 2015; Liu & Aberer, 2013; Wang et al., 2012; Yan, Guo, & Cheng, 2011; Yang, Long, Smola, Zha, & Zheng, 2011)

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.

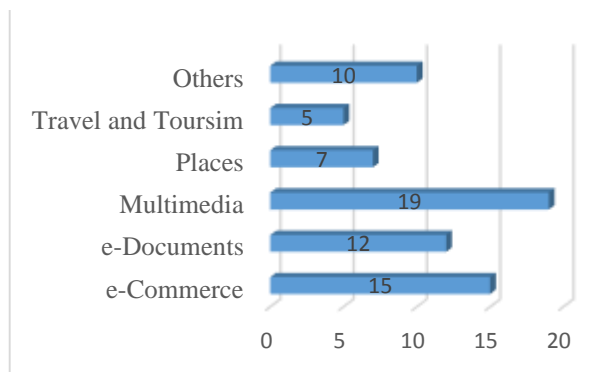


Figure 2 Distribution By Domain Of Applications

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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REFERENCES

- Adomavicius, G., & Tuzhilin, A. (2001). Extending recommender systems: A multidimensional approach. Paper presented at the Proceedings of the International Joint Conference on Artificial Intelligence (IJCAI-01), Workshop on Intelligent Techniques for Web Personalization (ITWP2001), Seattle, Washington, August.
- Alhamid, M. F., Rawashdeh, M., Al Osman, H., Hossain, M. S., & El Saddik, A. (2015). Towards context-sensitive collaborative media recommender system. *Multimedia Tools and Applications*, 74(24), 11399-11428.
- Alhamid, M. F., Rawashdeh, M., Dong, H., Hossain, M. A., Alelaiwi, A., & El Saddik, A. (2015). RecAm: a collaborative context-aware framework for multimedia recommendations in an ambient intelligence environment. *Multimedia Systems*, 1-15.
- Bagci, H., & Karagoz, P. (2015). Context-aware location recommendation by using a random walk-based approach. *Knowledge and Information Systems*, 1-20.
- Benlamri, R., & Zhang, X. (2014). Context-aware recommender for mobile learners. *Human-centric Computing and Information Sciences*, 4(1), 1-34. doi:10.1186/s13673-014-0012-z
- Biancalana, C., Gasparetti, F., Micarelli, A., & Sansonetti, G. (2013). An approach to social recommendation for context-aware mobile services. *ACM Transactions on Intelligent Systems and Technology (TIST)*, 4(1), 10.

- Bobadilla, J., Ortega, F., Hernando, A., & Gutiérrez, A. (2013). Recommender systems survey. *Knowledge-Based Systems*, 46, 109-132.
- Bouneffouf, D., Bouzeghoub, A., & Gancarski, A. L. (2012). Following the user's interests in mobile context-aware recommender systems: The hybrid-E-greedy algorithm. Paper presented at the Advanced Information Networking and Applications Workshops (WAINA), 2012 26th International Conference on.
- Castro-Schez, J. J., Miguel, R., Vallejo, D., & López-López, L. M. (2011). A highly adaptive recommender system based on fuzzy logic for B2C e-commerce portals. *Expert Systems with Applications*, 38(3), 2441-2454.
- Champiri, Z. D., Shahmiri, S. R., & Salim, S. S. B. (2015). A systematic review of scholar context-aware recommender systems. *Expert Systems with Applications*, 42(3), 1743-1758.
- Chan, W. K., Chiu, Y. Y., & Yu, Y. T. (2011). A web search-centric approach to recommender systems with URLs as minimal user contexts. *Journal of Systems and Software*, 84(6), 930-941.
- Chen, Z., Cao, J., Song, Y., Guo, J., Zhang, Y., & Li, J. (2010). Context-oriented web video tag recommendation. Paper presented at the Proceedings of the 19th international conference on World wide web.
- Codina, V., Ricci, F., & Ceccaroni, L. (2015). Distributional semantic pre-filtering in context-aware recommender systems. *User Modeling and User-Adapted Interaction*, 1-32.
- Colombo-Mendoza, L. O., Valencia-García, R., Rodríguez-González, A., Alor-Hernández, G., & Samper-Zapater, J. J. (2015). Recometz: A context-aware knowledge-based mobile recommender system for movie showtimes. *Expert Systems with Applications*, 42(3), 1202-1222.
- De Giusti, M. R., Villarreal, G. L., Vosou, A., & Martínez, J. P. (2010). An ontology-based context aware system for selective dissemination of information in a digital library. *arXiv preprint arXiv:1005.4008*.
- De Pessemier, T., Courtois, C., Vanhecke, K., Van Damme, K., Martens, L., & De Marez, L. (2015). A user-centric evaluation of context-aware recommendations for a mobile news service. *Multimedia Tools and Applications*, 1-29.
- De Pessemier, T., Dooms, S., & Martens, L. (2014). Context-aware recommendations through context and activity recognition in a mobile environment. *Multimedia Tools and Applications*, 72(3), 2925-2948.
- Durán, J. I., Laitakari, J., Pakkala, D., & Perälä, J. (2010). A user meta-model for context-aware recommender systems. Paper presented at the Proceedings of the 1st International Workshop on Information Heterogeneity and Fusion in Recommender Systems.
- Faraone, M. F., Gorgoglione, M., Palmisano, C., & Panniello, U. (2012). Using context to improve the effectiveness of segmentation and targeting in e-commerce. *Expert Systems with Applications*, 39(9), 8439-8451.
- Gallego, D., Woerndl, W., & Huecas, G. (2013). Evaluating the impact of proactivity in the user experience of a context-aware restaurant recommender for Android smartphones. *Journal of Systems Architecture*, 59(9), 748-758.
- Gantner, Z., Rendle, S., & Schmidt-Thieme, L. (2010). Factorization models for context-/time-aware movie recommendations. Paper presented at the Proceedings of the Workshop on Context-Aware Movie Recommendation.
- Gavalas, D., Konstantopoulos, C., Mastakas, K., & Pantziou, G. (2014). Mobile recommender systems in tourism. *Journal of Network and Computer Applications*, 39, 319-333.
- Gedikli, F., & Jannach, D. (2013). Improving recommendation accuracy based on item-specific tag preferences. *ACM Transactions on Intelligent Systems and Technology (TIST)*, 4(1), 11.
- Guo, G., Zhang, J., Thalmann, D., & Yorke-Smith, N. (2014). Leveraging prior ratings for recommender systems in e-commerce. *Electronic Commerce Research and Applications*, 13(6), 440-455.
- Hahn, J. (2011). Location-based recommendation services in library book stacks. *Reference Services Review*, 39(4), 654-674.
- Hariri, N., Mobasher, B., & Burke, R. (2012). Context-aware music recommendation based on latent topic sequential patterns. Paper presented at the Proceedings of the sixth ACM conference on Recommender systems.
- Hawalah, A., & Fasli, M. (2014). Utilizing contextual ontological user profiles for personalized recommendations. *Expert Systems with Applications*, 41(10), 4777-4797. doi:10.1016/j.eswa.2014.01.039
- Herlocker, J., Jung, S., & Webster, J. G. (2012). Collaborative filtering for digital libraries.
- Hidasi, B. (2015). Context-aware Preference Modeling with Factorization. Paper presented at the Proceedings of the 9th ACM Conference on Recommender Systems.
- Hidasi, B., & Tikk, D. (2015). Speeding up ALS learning via approximate methods for context-aware recommendations. *Knowledge and Information Systems*, 1-25.
- Hong, J.-y., Suh, E.-h., & Kim, S.-J. (2009). Context-aware systems: A literature review and classification. *Expert Systems with Applications*, 36(4), 8509-8522.
- Hong, L., Zou, L., Zeng, C., Zhang, L., Wang, J., & Tian, J. (2015). Context-Aware Recommendation Using Role-Based Trust Network. *ACM Transactions on Knowledge Discovery from Data (TKDD)*, 10(2), 13.
- Hussein, T., Linder, T., Gaulke, W., & Ziegler, J. (2014). Hybreed: A software framework for developing context-aware hybrid recommender systems. *User Modeling and User-Adapted Interaction*, 24(1-2), 121-174.
- Levi, A., Mokryn, O., Diot, C., & Taft, N. (2012). Finding a needle in a haystack of reviews: cold start context-based hotel recommender system. Paper presented at the Proceedings of the sixth ACM conference on Recommender systems.
- Li, Y.-M., Chou, C.-L., & Lin, L.-F. (2014). A social recommender mechanism for location-based group commerce. *Information Sciences*, 274, 125-142.
- Lin, Z. (2014). An empirical investigation of user and system recommendations in e-commerce. *Decision Support Systems*, 68, 111-124.
- Liu, X., & Aberer, K. (2013). SoCo: a social network aided context-aware recommender system. Paper presented at the Proceedings of the 22nd international conference on World Wide Web.
- Lombardi, S., Gorgoglione, M., & Panniello, U. (2013). The effect of context on misclassification costs in e-commerce applications. *Expert Systems with Applications*, 40(13), 5219-5227.
- Lu, J., Wu, D., Mao, M., Wang, W., & Zhang, G. (2015). Recommender system application developments: A survey. *Decision Support Systems*, 74, 12-32.
- Lutz, J., Thönissen, B., & Witschel, H. F. (2013). Breaking free from your information prison.
- Panniello, U., Tuzhilin, A., & Gorgoglione, M. (2014). Comparing context-aware recommender systems in terms of accuracy and diversity. *User Modeling and User-Adapted Interaction*, 24(1-2), 35-65.
- Park, D. H., Kim, H. K., Choi, I. Y., & Kim, J. K. (2012). A literature review and classification of recommender systems research. *Expert Systems with Applications*, 39(11), 10059-10072.
- Shi, F., Ghedira, C., & Marini, J.-L. (2015). Context Adaptation for Smart Recommender Systems. *IT Professional*, 17(6), 18-26.
- Teze, J. C., Gottifredi, S., García, A. J., & Simari, G. R. (2015). Improving argumentation-based recommender systems through context-adaptable selection criteria. *Expert Systems with Applications*, 42(21), 8243-8258.
- Wang, J., Zeng, C., He, C., Hong, L., Zhou, L., Wong, R. K., & Tian, J. (2012). Context-aware role mining for mobile service recommendation. Paper presented at the Proceedings of the 27th Annual ACM Symposium on Applied Computing.
- Woerndl, W., Huebner, J., Bader, R., & Gallego-Vico, D. (2011). A model for proactivity in mobile, context-aware recommender systems. Paper presented at the Proceedings of the fifth ACM conference on Recommender systems.
- Yan, X., Guo, J., & Cheng, X. (2011). Context-aware query recommendation by learning high-order relation in query logs. Paper presented at the Proceedings of the 20th ACM international conference on Information and knowledge management.

- Yang, S.-H., Long, B., Smola, A. J., Zha, H., & Zheng, Z. (2011). Collaborative competitive filtering: learning recommender using context of user choice. Paper presented at the Proceedings of the 34th international ACM SIGIR conference on Research and development in Information Retrieval.
- Yoshikane, F., & Itsumura, H. (2013). Book recommendation based on library loan records and bibliographic information.
- Yuan, Q., Cong, G., Zhao, K., Ma, Z., & Sun, A. (2015). Who, Where, When, and What: A Nonparametric Bayesian Approach to Context-aware Recommendation and Search for Twitter Users. *ACM Transactions on Information Systems (TOIS)*, 33(1), 2.
- Zarrinkalam, F., & Kahani, M. (2013). SemCiR: A citation recommendation system based on a novel semantic distance measure. *Program*, 47(1), 92-112.
- Zeng, C., Jia, D., Wang, J., Hong, L., Nie, W., Li, Z., & Tian, J. (2012). Context-aware social media recommendation based on potential group. Paper presented at the Proceedings of the 1st International Workshop on Context Discovery and Data Mining.
- Zheng, Y., Mobasher, B., & Burke, R. (2014). Context recommendation using multi-label classification. Paper presented at the 2014 IEEE/WIC/ACM International Joint Conferences on Web Intelligence (WI) and Intelligent Agent Technologies (IAT).